

PERCEPTION AND REPRESENTATION; THE 3D REVOLUTION

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ABSTRACT: Over the last decade, 3D technologies spread rapidly in every technical and scientific domain using representation systems. Cultural heritage conservation fields are one of them. The integration of 3D imagery is the source of as much enthusiasm as questioning about its relevance. When comparing 3D models to reality, the main question is to know whether it is a truthful reproduction of the studied object or not. This very simple question actually implies a much more complex answer, questioning first of all our perception skills and the very definition of perception itself. When comparing what we are able to perceive to the large spectrum of what is actually there, one can even ask about a clear definition of our so called reality. Is reality what we perceive? If it goes beyond, how can we develop and evaluate tools to reproduce it? The question is crucial as we are facing a tremendous change in the way we record and represent what we perceive. It requires to come back to a complete understanding of our perception skills, natural through our senses and artificial through the captors we develop. It also implies to look back at the way we used to represent “reality”, and how representation evolutions are intimately linked to societal changes.

1. INTRODUCTION

Working at first in the field of photography on one side and of geoarchaeology through Lidar datasets on the other side, a scientific collaboration led us to *Structure From Motion* (SFM) photogrammetry in order to complete Lidar datasets and to produce 3D models based on High Definition photos.

The initial postulate was that photogrammetry produces a truthful reproduction of reality, in terms of geometry and radiometry.

This simple but ambitious postulate was the source of a questioning as well on the scientific value of photogrammetric results as on the nature of the recorded information. What kind of information is recorded and can this information be considered as a reliable proxy of reality? If it can, what does reality exactly mean?

Furthermore, through the technologies we use as well as through the prevalence of vision over the other senses (smell, touch, etc.), the visual aspect of “reality” seems to have a dominant role. But is that what is visible enough to understand reality? Put differently, does visible information (geometry, radiometry) constitute a sufficient basis to

integrate the other “layers of information” (chemical, physical, historical, etc.) that can constitute what is called “reality”? These questions can be summarized in one simple interrogation: what is reality and what do we perceive of it?

Then, the questioning must be extended to our perception skills, and finally even to the notion of “perception”. But problems induced by 3D technologies, and specifically by photogrammetry, are not limited to questions about perception or information recording. The other side of this reflection is a questioning of the ways to represent this information. How do we represent 3D? Nowadays, through tables, 2D images, 3D models on a screen (2.5D) or 3D printing (which is a rematerialisation of what has been virtualised), depending on what part of it we need to emphasize. But none of these options seems to offer a complete answer.

As 3D technologies are currently developing and multiplying extremely rapidly, spreading in every technical and scientific domain, and particularly in cultural heritage conservation fields, these questions about perception and representation raise two practical issues:

Do these new methods replace traditional ones, and if they do in what aspects are they better ?

Are the results a true and fair view of reality, and how should they be approached ?

If social sciences such as archaeology prefer human-made observations, the reliable and objective expert eye, “hard” sciences would rather rely on the exhaustivity of teledection methods and their capacity to reproduce reality.

These two opposite postulates suggest that reality can be perceived in its entirety and that we have the tools to capture it. It seems relevant to ask ourselves about the true nature of what is called “reality” and about the limitations of our perception skills.

2. PERCEPTION AND REPRESENTATION

2.1 HOW DO WE PERCEIVE?

Humans perceive naturally through their senses and artificially through tools they develop. Naturally our sensory perception of reality is limited. Our field of view, the visible wavelengths, the sounds we hear, the sensitivity of touch, our sense of smell and taste are all variable and individual to each person, altering our perception of reality.

Our uniform conception of the human kind leads us to think that other people perceive in the same way we do. Thus, our sensorial reality would be universal. This conception prevents us to see and even understand the reality beyond our individual perception of things.

Through time, the scientific community identified inconsistencies between what we perceived and reality – the world is flat, the universe geocentric, matter is the produce of the five elements, light is only a wave, the human genome is composed of hundreds of thousands of genes etc. – to be assumptions that revealed themselves wrong.

To explain these inconsistencies, we develop tools that allow independence from our senses. Mathematics opened new fields of knowledge (optical science, physic, chemistry) and new tools (telescopes, chemical sensors, cameras).

Nevertheless, these tools are also limited. Even though they are based on mathematical principles, they are conditioned by our knowledge of the world and what we try to highlight.

Among five human senses, sight has been particularly developed. This fact is illustrated by the prevalence of visual representation ways. From paintings to writings, from photos to movies, every piece of information is communicated through visual signals. Thus, it is no surprise that technology followed the same path, from cameras to screens (two technological innovations that are now present everywhere).

Instead of talking about reality, wouldn't it be more relevant to talk about visible reality and focus on vision?

In order to capture visible reality, humans developed a tool based on their own anatomy. Optical devices such as digital cameras are indeed an alternative to human vision. This analogy makes the digital camera an observation tool as effective as the human eye.

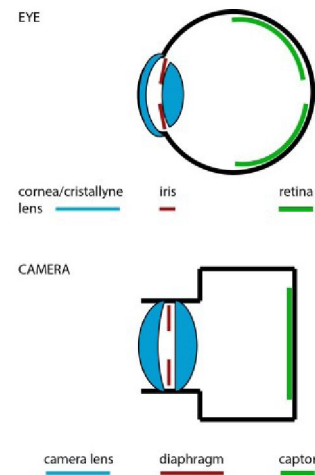


Figure 1: Analogy between eye and camera

The eye is composed of:

- The cornea and the crystalline lens: it is a transparent set focusing light on the retina and proceeding to the accommodation process.
- The iris: it is a circular membrane contracting and dilating itself to control the amount of light that falls onto the retina.

- The retina: it is a membrane covered with photoreceptor cells, called rod cells and cone cells, which turn the light signal into an electric signal. This makes it possible for the human nervous system to process. Cone cells are divided into three classes sensitive to wavelengths corresponding to red, green and blue [1].

The digital camera is composed of:

- The camera lens: it is an optical transparent set focusing the light on the captor. Depending on the type of camera lens, it is possible to adjust the field of vision.
- The diaphragm: it is a system composed of thin blades disposed around an opening (the aperture) used to regulate the amount of light reaching the captor of the camera. It is part of the camera lens.
- The captor: it is composed of photovoltaic cells measuring the intensity of light. Each cell is sensitive to wavelengths corresponding to red, green and blue. The measured intensity is translated into an electric signal.

Eye	Camera	Function
Cornea and critically lens	Camera lens	Light refraction
Iris	Diaphragm	Control of the amount of light
Retina	Captor	Light capturing
Brain	Processor	Image treatment

Table 1: Functional analogy of eye and camera

But perception is not only about "data capture" or recording. The visible information, acquired through the eyes or a camera, need to be processed. The definition of human vision includes a complex cognitive process involving memory. The role of individual memory in cognitive

processes is the reason why treatment of information can be considered as subjective. If it is clear how visible information is recorded, it cannot be considered as a full understanding of the perception process.

2.2 WHAT IS PERCEPTION?

As a first step, we need to understand what perception means. The first definition is connecting perception and sensations: perception is the action of collecting sensations through our sense organs about something in front of us. This definition suggests that what we perceive is a collection of signals providing access to an object. But what are these signals? Are they independent from each other or connected? Are they objective and universal, or characteristically linked to the object?

Gestalt theory provides a very pertinent answer. It proposes that sensations cannot be reduced to discrete signals, independent from each other, and connected from one situation to another in order to obtain perception. On the contrary, it claims that each signal we receive is linked to a coherent whole. When I hear the sound of a car, I know it is a car because this sound reminds me of other signals and of my own experience. It is characteristic of the car and gives me the ability to perceive and recognize it. Those signals we perceive are part of an identifiable whole. This entity is linked to each of its components and cannot emancipate itself from them because they provide its meaning. In the same way, when I listen to a melody, I hear the sum of several notes. The melody depends on a sequence of notes, and if I change a single note I change the whole melody. The melody cannot be reduced to a single note; it depends on the relationship between each note [2].

Moreover, I perceive this whole with my own experience and it reminds me of memories that are only mine. When I hear a car, I do not hear any car, but a car I know, or I believe to know.

Thus what we perceive is far from being an objective and truthful picture of reality. It is rather a fragmentary perception treated by our brain to give sense to our environment. The information we focus on (wavelengths received by the eye, sounds we hear...) is the result of our

evolution and fits with the needs of our lifestyle. It is also impacted by our individual physiology and experience.

Human vision cannot be dissociated from the treatment of the information perceived by the brain. The restitution process of visual information is not easy because the raw data remains inaccessible. The human brain is so sophisticated, and in a certain way “perfectionist”, that it is impossible to distinguish the aberrations induced by our physiological limitations. This is what happens with optical illusions, when in spite of the information transmitted through the eyes, the brain produces an image quite different from “reality”.

It acts on two main different occasions:

- When what you see is close to something you know: this is what Gestalt theory explains, perception is about the association of what you see and what you know. In order to go faster, our brain uses shapes and schemes to identify items – sometimes a bit abusively. On the figure below, we all see a triangle, even though there is none.

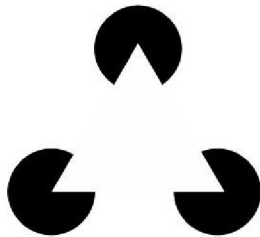


Figure 2: Gestalt classic figure of an imaginary triangle

- When the signal is incomplete: the eye is not a perfect device, and the repartition of photoreceptor cells leaves a blind spot on the retina (where the optic nerve is connected). However the brain extrapolates the visual information in order to fill this gap. In order to notice it, look at the figure below. If you hold this sheet of paper at a distance of 25 cm from your eyes, look at the R letter with your right eye and close the left eye (or L letter with the left eye, and close the right one), the other letter will disappear. This is your blind spot.

Of course, the interpretation part cannot be erased from the image analysis. Cognitive processes are necessary to understand the images, but they will be delayed by the use of digital cameras. This makes it possible to access the raw visual information without any subjective interference. When talking about 3D recording, the use of photos and photogrammetry produces an objective recording of what has been observed. An objective recording of reality provides a new tool to share what we perceive.

Indeed, if perception is an internal and individual process, how shall individuals compare their own perceptions and be sure that they "see" the same thing if not by a representation process?

One obvious representation process is a description through vocabulary, but the diversity and the limitations of vocabulary in the different languages is an important filter that transforms the mental images we have of reality. Subjectivity is also at stake because the use of vocabulary and the way each person involved understands it induces personal choices and experiences.

As the visual aspect of reality is the one we refer to, the most natural way to represent it is a visual representation. Before the invention of photographs, and without any technology, the simplest way to obtain a visual representation was to draw. Drawings, paintings, then photos, movies, and now 3D images show the evolution of the way humans perceive the world. How deeply are perception and representation processes linked? Is perception defining the ways of representation, or does representation changes our perception of reality?

R L

Figure 3: Demonstration of the blind spot

2.3 RECIPROCAL INFLUENCES

As a complex cognitive process, perception is influenced by the way of thinking, as is representation. Two main ways of

thinking are nowadays commonly recognised: circular and linear thinking. From circular thinking where humans are part of the world, to linear thinking where they are above everything; from the invention of perspective to the 3D vision; our conception of the world seems to evolve with the increase of our perception skills.

Circular thinking, or circular reasoning, has been attributed to "primitive" populations until it was recognised to be present in every human being (Levy-Strauss). It is a closed reasoning process, very delicate to use: which comes first, the chicken or the egg? None. The chicken is the cause of the egg and the egg of the chicken.

It is involving notions of reciprocity, equilibrium and exchange in a whole, which is reminding of the terms of Gestalt Theory. Circular thinking has also been called mystic thinking or symbolic thinking. Societies based on circular thinking are used to represent things according to their relative importance. For example prehistoric paintings, pre-Columbian representations or Christian medieval iconography do use proportions not with realism but with symbolism. The results are represented scenes with inconsistencies in the size of characters or objects, which actually translate their meaning and their place [3].



Figure 4: Engraved prehistoric map of Vallecamonica region in Italy (Sources: Archive Cultural District Vallecamonica)

Linear thinking, or linear reasoning, is based on cause-effect relationship. It is an opened reasoning process and a basis for all "exact sciences", "hard" sciences and many human sciences based on determinism, naturalism, or they seek for exhaustivity. Linear thinking is rational thinking, giving "simple" explanations to what is observable [4].

Rational thinking leads to rational representation, and our linear thinking society uses two simple notions to get "realistic" and rational representations: scaling and perspective.

During the Renaissance, the generalisation of perspective might have marked the final transition from a circular society to a linear one. The introduction of perspective had repercussions on the way people understood and visualised their world, with the large diffusion of pictures representing scenes (real or imaginary) with a "point of view". Of course, even the fact of choosing a point of view implies a subjective distortion of reality, but the result is a "realistic representation", meaning something everyone could see with their own eyes [5].



Figure 5: One of the first painting using fully perspective, by Masaccio, 1428 (Sources: «Loreto Fresko» by Melozzo de Forlì — EigenesFoto, aufgenommen am 23.09.2005. Under licence Public domain via Wikimedia Commons)

In the race for exhaustivity in the representation process, 3D technologies lead to major changes. The first characteristic of a 3D representation is that there is not "one point of view", but an "infinity of points of view". The choice of the point of view is deported from the source of the representation to its destination. If the introduction of the notion of "point of view" through perspective has been a true revolution at the Renaissance, what about the multiplicity of points of view through 3D representation?

Beyond the simple fact of documenting and representing reality (meaning all that is observable) in a very objective and complete way, nearly exhaustive, the 3D hyperdocumentation might be the manifestation of a change in the way we think.

3D, and now 4D (including time recording), makes it possible to have an overview free of subjectivity of the studied object. It finally enables a study of the processes and of the evolutions of the object, rather than a hyperdocumentation of fixed states. This is the dynamic animating interdisciplinary studies, like geoarchaeological ones.



Figure 6: Five random points of view of the 3D model of a castle in Burgundy before its restoration (Sources: CAPTAIR, 2014)

Looking back at the definition of circular thinking, is the use of 3D technology the manifestation of a new form of circular thinking, no longer mystic, but curious? What we might call "curious thinking" would be the research of a complete and objective understanding of a whole reality, complex product of what we can observe and how every part of it interacts.

3. CONCLUSION

The complex relationship between perception and representation leads to complex sociological evolutions, involving entire human groups as well as individuals. The issues implied by 3D representation are the indicators of a mutation of the way we "represent reality". We were used to 2D representation, with two particular cases: sculpture and perspective, aiming to reconstitute relief with more or less

realism. 3D technologies are nowadays shortening the gap between representation and visible reality.

The importance of this mutation should not be underestimated and it seems possible that the use of 3D technologies for scientific purposes, and now in daily life, may have as significant a societal impact on our vision of the world as had the introduction of perspective during the Renaissance. This impact might already be observable at the individual and generational level if young adults and children prove themselves to be more skillful with 3D models than older people. To illustrate how strongly our society is changing its perception of the world, it is easy to mention the common use of GoogleEarth, giving to anyone a dynamic, multiscale and tridimensional vision of our planet.

If 3D technologies provide us with a new way to represent our world, they also imply a tremendous change of our perception of reality. What are the consequences of such an evolution on our society? How should we face the challenges coming with it? Hyperdocumentation, Big Data issues, interactivity, immersion, augmented reality, etc. These new concepts are revolutionizing our lifestyles, and tomorrow we may not see the world in the same way.

4. ACKNOWLEDGMENT

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