



## The photographic sign and the trichotomy of the trace

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### ABSTRACT

This article offers a novel perspective on the specific understanding of the photographic sign, situating the trace at the core of its functioning. The photographic sign is subjected to Peirce semiotics analysis, which reveals its underlying structure. This decomposition allows the establishment of a semiotic model that clarifies the essence and characteristics of photography and draws certain broader lessons about the notion of trace. On this basis, three categories of object are distinguished: the trace, the indicant and the print. These three objects constitute what we call the *Trichotomy of the trace* which takes on its full meaning in the forensic field. Building upon this triadic model and our analysis of photography, we propose a refined definition of the trace.

### 1. Introduction

"If the definition of the term 'photography' requires no elaboration, it might be beneficial to elucidate the concept of 'police'"<sup>1</sup> noted Matherer in the introduction of one of his publications ([18], p. 313). The present article takes a reversed approach: let us first establish a comprehensive definition of photography to facilitate an understanding of its legal implications and to glean essential insights concerning the notion of trace.

Photography occupies a particular category within the realm of images. The concept of image is intricate and multifaceted, encompassing aspects such as media, medium, act, crime, digital files, fixed or animated, recorded or fabricated, authentic or manipulated, testimony, arguments, etc. Despite this complexity, a fundamental commonality unites all images: analogy. "An image is foremost something that bears resemblance to something else"<sup>2</sup> ([16], p. 31). According to Hofstadter and Sanders, analogy is a mental process of relating two situations based on perceived similarities between them. "To make an analogy is to perceive 'the same' beyond the differences"<sup>3</sup> ([26], p. 7). They argue that analogy is not just a type of formal reasoning that belongs to the same family as deduction, induction and abduction, but is ubiquitous in all areas of cognition: perception, memory, language and learning [11]. It creates links and bridges between our concepts and our environment, between our past and our present. Without necessarily contradicting these

authors, we suggest the hypothesis that analogy is a mental process that is essential for considering anything as a sign: without analogy, there is no possible perception of the "same" and therefore no sign, just a thing. Analogy would be the indispensable and omnipresent fuel and fire of the determination of something as a sign, the premise of all semiosis.

Embracing analogy as the cornerstone of images entails acknowledging their nature of representation: the image is not the object; it is a representation of another object. Moreover, an image maintains a certain relationship with its object, its *referent* to use Barthes's terminology ([2], p. 18). This relationship would be of the order of analogy ([16], p. 31), established through certain "similarities" between the image and its referent. One such similarity often pertains to a visual resemblance aligning with direct human perception of the represented referent in a photographic image.

Considering the image as an *analogical sign* prompts an exploration of its signification and the mechanisms governing its production of meaning. Peirce's semiotics offers an invaluable theoretical framework for scrutinising photographic images, particularly in the forensic field [7]. Delving into the intricate details of Peircean semiotics is not imperative to our analysis. Instead, we extract pertinent elements to guide our investigation.

Peirce defines a sign or *representamen* as "something which stands to somebody for something in some respect or capacity" ((2.228) [20], p. 99). The Peirce sign theory imposes at least three main distinctions:

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<sup>1</sup> Free translation of "S'il est superflu de définir le sens du mot « photographie », il peut être utile de préciser ce qu'est la police" ([18], p. 313).

<sup>2</sup> Free translation of "Une image, c'est d'abord quelque chose qui ressemble à quelque chose d'autre" ([16], p. 31).

<sup>3</sup> Free translation of "faire une analogie, c'est percevoir « le même » au-delà des différences" ([26], p. 7).

- 1) The initial distinction lies in the demarcation between the external world of fact from the internal world of fancy ([20], p. 87). A photograph resides in the external world of fact that the perception by a potential interpreter could create a sign in his internal world. This sign establishes a triadic relationship among three entities: the representamen, the object through the interpretant. At the interface between these two worlds is the sensory system. The *sensory image*, as understood in this context, is intrinsically linked to human sensory capacity to detect external world signals instantaneously and continuously. This sensory process exclusively operates when the object is physically present in the external world ([22], p. 22). Although this sensory perception can encompass various signal types (auditory, olfactory, gustatory, tactile, visual), our focus here remains primarily on its visual manifestation. It differs from the *mental image*, which is a cognitive representation activity originating in the internal mental world and not necessarily triggered by the sensory image's signal.
- 2) The second discerns the levels of the hierarchical logic defined by Peirce between three categories of being ([20], p. 75). The relation of the sign to its object can be of the order of the qualitative resemblance of the *icon* (Firstness), the physical contiguity of the *index* (Secondness), or the convention of the *symbol* (Thirdness). Dubois [19], reflecting on the ontological principles underpinning photographic messages, expounds three successive discourses aligned with this hierarchical logic. The character of the imitation of reality is the first discourse that has accompanied photography since its invention ([19], p. 23). This first shibboleth assumes that the mimetic capacity of photography derives from its mechanical and physico-chemical process, which excludes human intervention. The photographic lens automatically produces an image that precisely imitates reality on the sensitive medium during the exposure phase. From this ability to automatically imitate reality, a division between science and art emerges opposing technical objectivity against human subjectivity and skill. The concrete and objective documentary function for photography, the imaginary creation freed or not from reality for art ([19], p. 26). The documentary function associated with the mimetic result of reality gave rise to numerous scientific applications of photography in the 19th century, notably within the pioneers of forensic science: "*This is not the forum for debating whether photography is an art or a science [...]; however, it is unequivocal [...] that it has become the artificial memory of humanity and the automatic and impartial recorder of events. Both these faculties profoundly interest the criminalist.*"<sup>4</sup> ([23], p. 1). This discourse on photography as a mirror of reality articulated here by Reiss, rests primarily on the iconic essence of the photographic sign, i.e. its capacity to automatically reproduce the qualities and characters of its referent. In contrast to the iconic imitation of the 19th century, a second discourse centred on *the reality effect* of photography was established during the 20th century. This perspective challenges both photography's imitative aptitude and its "automatic" character of recording characteristic. Limitations such as dynamism and resolution constraints, distorted colour rendition, two-dimensional reduction, and exclusively visual representation now come to the fore. Photography ceases to be an automatic replica of reality, instead of transforming into an intentional, culturally encoded creation authored by a photographer. Objective automatism gives way to the photographer's language of choices, expressiveness, optics, lighting, etc. Photography identity transitions from an automatic mimicry of reality to a purposeful, convention-laden artefact fashioned by its creator. The third

discourse, the most recent and ensuing structuralist deconstruction of the reality effect, reintroduces the concept of reality into images, no longer as a mimetic outcome, but as a trace. A photograph no longer merely "resembles" its referent; it is intrinsically determined by it. "*A photograph [...] is a direct sampling of the real [...] as brought forth by photographic chemistry. This recalibrates everything. It recalibrates everything, especially in regard to the subject of enunciation*"<sup>5</sup> ([4], p. 31). This discourse does not deny prior codifications but rather redefines the physical connection and essential presence of reality in photography. A photograph essentially attests the existence of its referent but does not possess direct meaning. Its core essence becomes pragmatic, inextricable from the experiential reality of its referent, as opposed to semantic – akin to a trace, it lacks inherent meaning ([19], p. 70). Rooted in its mode of production, the physical contiguity with its referent at the moment of capture inscribes the essence of photography in Peirce's class of indices (Secondness).

- 3) The third fundamental distinction emerges not directly from Peirce's theory but from the aforementioned discourses, particularly the last one related to the *trace*. Indeed, it particularly highlights the importance of knowledge about the genesis: the mode of production of the sign is complementary to its result or factual state. Consequently, the photographic essence emanates not from its mimetic outcome but from its production process that strictly necessitates a physical connection with its referent.

These concepts surrounding the photographic sign swiftly coalesce to establish the photographic principle: it essentially stems from recording a physico-chemical trace ([27], p. 13). Acknowledging and considering this principle related to the Secondness of the index yields profound implications for interpretation, anchoring it to a state of existence – a reality that existed in a certain past: Barthes's "that-has-been" noema of photography ([2]: 120).

To further our exploration of photography, it becomes imperative to refine the notion of a "trace", drawing on an existing definition from the realm of forensic science.

## 2. The photographic trace

### 2.1. The definition of the trace

There exist multiple definitions for the concept of *trace* within the forensic domain. A recent interpretation links *trace* with the notion of modification [13]. However, we opt not to adopt this definition in the context of our work, finding it challenging to manage and incongruent with our analysis for various reasons. Our earlier discussions concerning the semiotic significance of the distinction between genesis and its outcome have underscored the relevance of this differentiation. Notably, this complexity remains unaddressed within the concept of modification. A modification fails to qualify as either an observable outcome or a mode of production; instead, it denotes a discrepancy between an initial state – which is sometimes undetermined – and a final state. This raises several unanswered questions in the context of our analysis: what exactly is observed in a modification? What characterises its mode of production? What is the trace of a modification? Those questions remain unanswered in their refined conceptualisation of fuzzy-defined entities, which continues to rely on the same notion of modification [5].

From an epistemological stance, to pursue our inquiries, it seems more relevant to embrace a definition of the trace perceived as a *vestige* or a *remnant*: a persistent result of something [17,25,6]. Therefore, we choose to rely on the definition proposed by Margot: "*mark, signal or object, a trace is an apparent sign (not always perceptible to the naked eye). It*

<sup>4</sup> Free translation of "*Ce n'est pas ici le lieu de discuter si la photographie est un art ou une science [...]; mais ce qu'on peut affirmer [...] c'est qu'elle est devenue la mémoire artificielle de l'humanité et l'enregistreur automatique et impartial des événements. Ce sont ces deux facultés qui intéressent tout spécialement le criminaliste*" ([23], p. 1).

<sup>5</sup> Free translation of "*La photographie [...] est un prélèvement direct de réel [...] que la chimie photographique fait apparaître. Ça change tout. Ça change tout quant au sujet de l'énonciation, notamment*" ([4], p. 31).

is the remnant of a presence and/or an action at its location"<sup>6</sup> ([17], p. 74).

In the context of Peirce's classification of signs, Margot characterises the trace as an indexical sign. This designation is based on the premise that a material trace is a sign that possesses a genuine and distinctive existence, intrinsically linked to its referent through physical contiguity. When defining photography as the recording of a signal – a trace of something – it is reasonable to classify photography in the same category of signs.

This definition confers on traces three different possible materialities: mark, signal or object. Nevertheless, it fails to delineate certain implications that its own materiality might entail. Five interconnected attributes arising from the materiality of a trace encompass: (1) its existence independently of its source's simultaneous presence; (2) the spatial distance from its source; (3) its temporality; (4) its own characteristics; and (5) whether it involves specific methods for recording or detecting

- (1) There is no doubt that the materiality of the mark and object can persist for a relatively long time in the absence of their source. However, signals, once emitted irreversibly, exhibit a distinct behaviour. Signals might travel very quickly and over a long distance in the case of electromagnetic radiation, or more gradually, exemplified by temperature changes or odours, thereby persisting longer in the absence of their source but within a limited range. The emission of electromagnetic radiation ends as soon as its source is no longer present. Thus, depending on the ephemeral duration of its existence, the signal requires near-immediate recording or detection concurrent with the event, lest it be lost forever. In the realm of photographic recordings, near-simultaneity with the emission of the electromagnetic signal trace is necessary, requiring the presence of the referent. This temporal alignment is a matter of distance: the observation of distant celestial bodies occurs long after the signal emission, but once it has passed and no longer emitted by the referent, the signal can no longer be detected or recorded.
- (2) Unlike a footprint or signature necessitating physical contact at the location of the mark on its substrate, a photographic trace demands distance from its referent. The trace-signal emanates from the referent, akin to a projected substance. Unlike the latter, it disperses in a continuous, linear manner and potentially radiates in all directions from the referent's surface. The varying distances – from microscopic for detailed observations to intermediate for traditional observations and expanding for cosmic exploration – are intrinsic to the photographic trace. This distance also implies a certain angle of reception of the signal in relation to the referent. The angle of view and the distance have a fundamental impact on the representation. Some authors ([28] in [15], pp. 75–78) associate this distance with a form of *absence* of the referent, because it implies no *contact* as for a signature which requires the contact with the document. Associating this distance with absence is misleading and contrary to the strict requirement of the referent's presence at a certain distance. Moreover, before being captured, the electromagnetic signal is also determined by contact with the referent. However, once captured, the referent is made *absent* as his physical presence is no more required by the photograph itself. A photograph is an autonomous record of a trace and must be considered as such. It is an *object* independent of the trace itself. In contrast, a signature embodies the trace, which also necessitates a particular distance anyway as the

author manipulates an instrument. The nature of these two entities is fundamentally different.

- (3) The photographic trace is intrinsically linked to the referent's concurrent presence. This distinguishes it from other traces, as the electromagnetic signal continuously and irrevocably emitted by the referent, perpetually evolving alongside it. Each *instant* of this trace-continuum is unique and irremediably ephemeral at a specific location, inseparably intertwined with the referent's state. Thus, the photographic trace is engraved in the "quasi-present" of the fact. Additionally to this simultaneity with the fact, the recording process entails a certain exposure duration, a temporal pause in the continuum of signal emission, perpetually in tension with the signal's dynamic progression. In this sense, instantaneous photography - with a very short exposure time - represents a major and indispensable advancement in the non-posed recording of facts and events.
- (4) The signal, vector of certain qualities of its individual source, possesses inherent attributes arising from its material nature. Light possesses distinct properties of propagation and natural interaction contingent upon the composition of the emitted signal trace resulting in phenomena like interferential colours creation, light polarisation, and refractive properties [29]. These specific properties can modify the signal emitted by the referent. Understanding and identifying these effects is imperative for appropriate action during creation or interpretation to ensure suitable contrast.
- (5) Unlike a mark left by contact, which might persist under adverse conditions and be discovered later, light signals mandate immediate detection or recording, coincident with their emission and at a defined distance. Photography aligns with computer logs, continuously and contemporaneously recording activities across computers, servers, and interconnected electronic devices. Despite being a constraint, this enforced synchronicity between photographic recording and factual occurrence presents remarkable opportunities. Surveillance cameras, for instance, have grown significantly and are used as live crime detection tools for intervention, prevention, or investigation ([24], p.215). Simultaneous recording also safeguards the trace in comparison to other types of traces that might experience alterations before detection and preservation due to the passage of time and contamination ([17], pp. 75–76). Recording secures the trace's state for subsequent analysis, illustrating its potential utility and resilience.

## 2.2. Photonic image vs analogical view

The photographic process involves the recording of a signal through amplitude modulation, which is subsequently sampled and quantified. The resulting image can be envisioned as a discrete array of pixels (sampling) each assigned a digital value (quantisation) corresponding to a grayscale level (inversely related to negative density) [1]. This interpretation stems from the physical materiality of the recording of the trace, i.e. the physical transformation and quantisation of photon energy at each sensor point. This informational level relates to the *photonic image* ([27], pp. 15–32). The photonic image is the material outcome of the principle of photography: the recording of the signal-trace into a sampled and quantified matrix. The essence of photonic image is digital, open to various interpretations: spatial, differential, frequential.

However, humans do not naturally perceive the photographic image in this digital manifestation. Its reception does not occur at the material level of a quantised pixel matrix; instead, it is experienced as an *analogical view* ([27], p. 28) much like other image types. There undoubtedly exist iterative connections between the photonic image and its analogical view, perceived by interpreters. Yet, these connections delineate two distinct informational systems.

Just as we distinguish between the informational systems of the

<sup>6</sup> Free translation of "Marque, signal ou objet, la trace est un signe apparent (pas toujours visible à l'œil nu). Elle est le vestige d'une présence et/ou d'une action à l'endroit de cette dernière" ([17], p. 74).

photonic image and the analogical view, differentiation is crucial for their respective modes of reception ([27], pp. 74–80). Mathematical (or cybernetic) reception operates upon the photonic image, while human analogical reception relies on the analogical view.

Following the acquisition, the photonic image corresponds to the level of calculation, processing and analysis by the computer. Mathematical reception of the photonic image can exist within a completely isolated environment, lending itself to full digitisation and automation. The analogical view and human intervention are totally incidental, or even excluded from the process. This closed-loop system evolves further with the advancement of artificial intelligence and Big Data-driven automation: automatic identification and pattern recognition, mathematical manipulation of outcomes through comparison with extensive databases.

### 2.3. The implications of the photonic index

Drawing from Peirce's semiotics, Dubois ([19], pp. 60-70) expounds upon several inherent consequences of the index, which also extend to photography. Treating photography as an indexical sign primarily involves the photonic image's material nature, comprehended by interpreters aware of its production process while perceiving its analogical representation. These consequences embody the four principles of individuality,<sup>7</sup> unity, attestation, and designation.

#### 2.3.1. The principle of individuality

"Indices refer to individuals" ((2.306) [21]). The term "individual" should be comprehended within a philosophical context of identity: a specific element within a population with distinct *numerical identity*. The principle of individuality within indices is founded on the physical contiguity with its referent. According to this tenet, a photograph, as the outcome of an act of recording a trace emitted by an individual referent at a specific time, in a specific place and under specific conditions, is equally individual. The referent's numerical identity implies that of the trace and its recording.

The numerical identity of an individual does not necessarily entail qualitative distinction from another similar individual. Such instances are what can be termed as replicas: real objects that are (almost) qualitatively indistinguishable, solely by their unique numerical identity. Therefore, individuality does not inevitably equate to singularity in the sense of uniqueness. Replicas, having closely or indistinguishably similar attributes, can manifest at the referent, trace, or record level. Here are a few examples:

- a) The referent: an ammunition box contains 50 qualitatively indistinguishable cartridges. Each cartridge is a replica, yet distinct from numerical identity, as there are 50 "different" ones. Any indistinguishable replica can be captured in photographs without impacting the result. The physical connection to the chosen individual is made, but it remains indistinguishable, regardless of the replica chosen.
- b) The trace: a fingermark is captured multiple times consecutively under consistent conditions. In this scenario, the same individual fingermark will emit a consistent signal under uniform lighting conditions during the various recordings. While these shots are replicas in the sense of resembling each other, they each possess nonetheless their own numerical identity.
- c) The record: a single shot – or a digital file – can easily be replicated extensively and distributed globally. All these replicas share the same original recording of the individual's trace and are qualitatively indistinguishable.

In response to the challenge posed by the indistinguishability of

replicas, industries and societies often introduce identifiers (such as model number, batch numbers, serial number, logos, increments, etc.) or incorporate metadata (date and time, GPS coordinates, production sites, authorship, etc.). This concern also holds significance within the forensic domain, where a comprehensive system of identifiers unique to each object of interest is implemented alongside documentation and photographic inventories. These identifiers are positioned near the object of interest to appear within the shot. This approach to integrating identifiers, along with the process of photographing relevant referents, forms the foundation of the chain of custody's concept ([12], p. 206).

The principle of individuality of indices should not be confused with the process of *source* identification or individualisation ([14], p. 1). The former specifies the essential individuality of the index and its referent, grounded in physical principles of index production. A photograph embodies an individual record exclusively influenced by a signal emitted by an individual referent. The latter is a cognitive process that carries inherent uncertainty. The principle of individuality of indices, however, remains a fundamental premise of the source identification process.

#### 2.3.2. The principle of unity

The photographic image is an outcome characterised by a dual spatial and temporal segmentation. This double cut occurs within the singular act of exposure. Photography, through the genesis of its production and the simultaneous occurrence of the act with the presence of the referent, imparts spatial and temporal unity to its analogical representation and the referential scene. The perceptual field created by an interpreter's analogical view implies a consideration of this temporal and spatial unity whatever the accurate characteristics of the respective cuts. The analogical view of a photograph is not considered as a composite of multiple spaces, akin to a Cubist pictorial arrangement. Any such perception would strip it of its photographic essence, potentially transforming it into a photomontage. Considering the temporal cut, an additional challenge lies in the uncertainty around the actual exposure duration, which may not be explicitly evident in the perceived analogical view. The principle of temporal unity inherited from the creation of the photograph does not inherently provide insight into the duration of the cut, sometimes leading to fractures or misconceptions. For instance, a lengthy exposure might exhibit the appearance of a snapshot due to the subject's immobility, creating a disjunction in reception. Techniques involving luminescence, like Luminol, can necessitate extended exposures, concurrently with chemical applications. This can erroneously prompt interpreters to perceive the resulting photograph as a snapshot. This temporal disjunction can introduce inconsistencies in the perception of temporal unity within the image. In certain cases, the operator's movements while applying the chemical might be partially captured, leaving ghostly shadows within the photograph.

#### 2.3.3. The principle of attestation of existence

The index, effectively affected by its referent, inherently attests to the presence, existence, and specific *qualities* of its referent, within its temporal and spatial context and in the conditions of its genesis. In the same way that a GC-MS analysis confirms the presence of certain compounds within a substance through the recording of a mass spectrum, a photograph attests to the visual attributes of its referent. "Before a photograph, consciousness does not necessarily delve into nostalgic recollection [...], but it follows the path of certainty with any extant photograph in the world: the essence of photography lies in authenticating its representation. Each photograph stands as a certificate of presence. This certificate signifies

<sup>7</sup> The term individuality principle is preferred to the singularity principle initially proposed by Dubois.

the new trait that its inception introduced into the realm of images"<sup>8</sup> ([2], pp. 133–135).

While the index attests to the presence, existence and certain qualities of its referent through contiguity, it never claims to provide the entire picture. Again, this principle of attestation should not be conflated with the process of source identification. Like the principle of individuality, the attestation principle is also a fundamental premise of the source identification process. Anti-doping serves as a notable example of this distinction: the analysis (or recording of the trace signal) attests to the presence of a prohibited substance in a sample, yet does not divulge its origin (source) or mode of entry (activity) into the sample.

Capacity of photography to accurately depict visual attributes (shape, size, textures, appearance, etc.) of reality, often resembling human sensory vision, bolsters its power of attestation: "it has become the artificial memory of humanity and the automatic and impartial recorder of events"<sup>9</sup> ([23], p. 1). Conversely, such a claim might not be applicable to other forms of evidence in terms of their attesting or testimonial capabilities. Society and governmental institutions recognise this attestation potency, using photography in identity verification documents for authentication.

The principle of attestation underpins numerous applications of photography within the forensic realm, including:

- A means of confirming an individual identity through a visual image. Louis Bertillon's codification of the mug shot format in 1886, aimed at achieving this very purpose, integrated within a comprehensive anthropometric identification system [3].
- Tool for documenting locations (since 1868): "Photography was finally recognised as capable of scrupulously recording everything, and details that might be overlooked during observation but visible in a photograph could acquire vital significance later on."<sup>10</sup> ([23], p. 15)
- A forensic instrument for recording and attesting observations made by criminalists, who photograph fingerprints, observations, etc., not only to facilitate working with these elements but also to preserve (record) them and attest to their existence, visual attributes, and locations.
- Surveillance system (since 1900), which, apart from preventive utilities, document actions. The detection capabilities of surveillance emerged later, requiring a continuous stream of images that can be remotely accessed simultaneously.

The quality of the photonic image, specifically its accuracy in visually representing the referent or real phenomenon, holds paramount significance within the principle of attestation of the "that-has-been" and the "as-it-was" ([2], p. 120 et 16) : sharpness, exposure, resolution, and the lens's faithfulness in reproducing reality.

### 2.3.4. The principle of designation

"The index asserts nothing; it only says, 'There'! It takes hold of your eyes, as it were, and forcibly directs them to a particular object, and there it stops" ((3.361) [21], p. 144). It indicates. Thus, as a complementary aspect attesting the existence of its referent, it designates what is to be

<sup>8</sup> Free translation of "Devant une photo, la conscience ne prend pas nécessairement la voie nostalgique du souvenir [...], mais pour toute photo existante au monde, la voie de la certitude: l'essence de la Photographie est de ratifier ce qu'elle représente. [...] Toute photographie est un certificat de présence. Ce certificat est le gène nouveau que son invention a introduit dans la famille des images" ([2], p. 133–135).

<sup>9</sup> Free translation of "elle est devenue la mémoire artificielle de l'humanité et l'enregistreur automatique et impartial des événements" ([23], p. 1).

<sup>10</sup> Free translation of "On avait fini par reconnaître que la plaque photographique était capable d'enregistrer scrupuleusement tout et que des détails négligés au constat, mais visibles sur l'image photographique, pouvaient acquérir dans la suite une importance capitale." ([23], p. 15).

observed.

Similar to individuality and attestation, the potency of designation does not uniformly apply to all indices. Not all photographs possess equal clarity of designation for an interpreter in terms of what should be observed. This principle of designation forms the foundation for various applications of photography by law enforcement, such as

- Wanted posters: This extends beyond attestation to encompass designation: it points to *him!*
- Investigative tool: The focus now shifts to situating the observation, contextualising it, indicating it, and highlighting it. *Here!* Additionally, criminalists use markers at crime scenes for designating the locations where items have been discovered. The numbering of these markers is rather aligned with the concept of individuality.

In this principle of designation, the temporal and spatial cuts of the photographic recording, in conjunction with the staging of the referent and its illumination are of paramount significance. "See, here, [...] there" ([2], p. 16).

It is important to remember that these four principles pertain to the process of recording, and by extension, to the photonic image. At the level of the photonic image, functioning as an index, the photograph stands as distinct, attests to its referent's existence, and designates what should be observed. Yet, it does not articulate or signify anything.

The interpretation of the index lies within the interpretant of the receiver, and by anticipation, of the emitter through cultural coding. Thus, the interpretation is contingent upon the interpreter's analogical view, not the photonic image itself. Prior to delving into the workings of photographic signification, it is essential to clarify certain aspects pertaining to the concept of an index.

## 3. Trace, index and indicant<sup>11</sup>

Throughout our discourse, we have employed several terms (such as sign, record, trace, and index) and have previously provided definitions for these concepts. However, certain aspects still require elucidation. Indeed, what distinguishes a trace from an index? Does the act of recording a trace automatically endow the recording with the status of a trace? Addressing these seemingly simple questions is not as straightforward as it may seem and requires the introduction of a new concept referred to as an *indicant*.

### 3.1. The relationship between the trace and the index

"A trace is an apparent sign" ([17], p. 74). To comprehensively grasp the distinction between a trace and an index, it is imperative to deconstruct this statement further. To be precise, a trace is not intrinsically a sign: it fundamentally embodies a vestige of something. It exists whether or not an interpreter subsequently recognises it as a sign. In Peirce's semiotic framework, a sign is a triadic relationship encompassing a *representamen*, an *object*, and an *interpretant* within the interpreter's internal realm. Consequently, a trace is an object in the external world – or a *sensory image*, direct perception of the external world – that could produce a sign for an interpreter establishing a triadic relationship in his internal world. In Peirce's terminology, it corresponds to a specific type of sign through its relationship of physical contiguity with its referent: an *index (indexical sign)*. Based on this statement, we hold a different perspective than Dulong who postulates "that a trace has no reality except through the perception of an observer [...]. To acquire a presence, it is therefore necessary that it be perceived by a person competent to read this

<sup>11</sup> The term *index* is used in regard to Peirce's semiotic which corresponds to the word "indice" in French. The English word *indicant* is then chosen to express the idea of the French word "index". So the three words *Trace*, *indice* and *index* in French correspond respectively to *trace*, *index* and *indicant* in English.

type of trace. [...] This is why we speak of the "invention" of the trace" ([8], pp. 262–263)<sup>12</sup>. If we agree on the necessary competences of the *interpreter to perceive a trace as a sign*, in our opinion, the "invention" of the trace is misplaced by Dulong. There is no "invention" of the trace: a trace exists regardless of its detection or its interpretation as a sign by an interpreter. Instead, the "invention" must then be attributed to the level of the sign: the indexical sinsign in its triadic structure.

### 3.2. Is the photonic image a trace?

We have expounded in a descriptive and neutral manner that the photonic image is a recording of a signal emitted by its referent. The question that now arises is whether the recording of a trace of a referent inherently transform this recording itself into a trace, a vestige of its referent. Following the definition provided above, nothing prevents it: the photonic image constitutes a tangible object, a vestige of a signal's presence emitted by something. Thus, the photonic recording would indeed be a trace of another trace (a signal) referring to the same initial referent. However, this proposition prompts a degree of unease surrounding the concept of a trace. This confusion stems from the lack of precision within the definition itself. A trace inherently possesses an *automatic* or *incidental* nature in its genesis, a quality devoid of intrinsic communicative intention, which the definition fails to explicitly capture. By communicative intention we mean the fact of intending to exchange a message between sender and receiver through signs. Similar to photography, the essence of a trace lies not in its observed outcome – the vestige – but in its automatic process of creation. Considering only the photonic image, then yes, it can be considered as a trace. However, as we have seen from the various discourses that have accompanied photography, it is also the product of a communicative act.

Thus, despite the automatic nature of its production, a photographic recording deviates from the trace due to its typically human-mediated communicative act. This *intentional* act in the creation process is termed *index* by various French authors ([15], p. 74; [27], p. 47; [10]) which corresponds to the term of *indicant* that we adopt to distinguish it from Peirce's notion of *index*. The operator of an indicant conveys a message and seeks to communicate something through this presentation. An indicant exhibits a strong designating aspect coupled with a quest for meaning in its very genesis. Additionally, this intentional utterance can establish a communicative loop between a transmitter (operator) and a recipient when these two entities are distinct. Nevertheless, these authors place the distinction between automatic vestige and communicative act at the level of Peirce's triadic sign. However, this distinction should be situated at the genesis of the trace by an emitter. Given its automatic nature, a trace is a pure vestige totally devoid of communicative intention from the emitter. Conversely, an *indicant* is a deliberate vestige created by an operator with an intention of signifying something to someone. "*The very opposite of the trace, which is essentially involuntary*"<sup>13</sup> ([17], p. 81). Margot indeed attributes the involuntary nature of a trace to differentiate it not from an indicant, but from another concept termed "print".<sup>14</sup> However, a *print* differs from an *indicant*. In addition to its voluntary aspect, a *print* stands apart in that its referent is determined irrevocably or indisputably: it saturates the determination of the referent. A *print* corresponds to the referential material ([17], p. 81).

Before delving into examples relating to these three concepts—trace, indicant, and print—it is essential to clarify the meaning of *voluntary* to

<sup>12</sup> Free translation of « *qu'une trace n'a de réalité que par la perception d'un observateur [...]. Pour qu'une trace acquière une présence, il est donc nécessaire qu'elle soit perçue par une personne compétente à lire ce type de trace. [...] C'est pourquoi l'on parle de « l'invention » de la trace »* » ([8], pp. 262–263).

<sup>13</sup> Free translation of "*Tout le contraire de la trace qui, par essence, est involontaire*" ([17], p. 81).

<sup>14</sup> "*Empreinte*" in french.

prevent any potential confusion. The operator's intention of an indicant pertains to communicational aspects. Thus, an indicant fundamentally relies on the informational medium of the analogical view, rather than solely on the physical process of photonic image recording. From the indicant's inception, the operator possesses a voluntary communicative intention to designate something for someone to signify something.

#### 3.2.1. A few examples

(Trace) A fingermark discovered at a crime scene, left as a consequence of the perpetrator's actions, qualifies as a trace. It is an automatic remnant arising from the activity that generated it. The perpetrator lacks any communicative intention and may not even be aware of its production.

(Trace) When burglars forcibly open a lock, they inevitably leave toolmarks on the cylinder. These marks result from a deliberate action, yet the intention solely pertains to the breaking-in process. The traces, in this context, are merely incidental byproducts of the forced entry. Even though the burglar might be aware of their presence, there is no underlying communicative intention behind leaving those toolmarks.

(Indicant) In contrast to the previous example, a false fingermark intentionally placed at a crime scene by a perpetrator to mislead an investigator is not classified as a trace but as an indicant. Given the circular communicative process between the emitter and the receiver, the latter may mistakenly perceive it as a trace. In a similar scenario, counterfeit or deepfake images can deceive the observer into perceiving it as a genuine photonic recording when, in reality, it is a fabricated creation.

(Indicant) Consider explorers navigating a dense jungle who leave visible marks along their journey. These marks, created during their progress, do not fit the definition of traces but rather indicants. Their communicative purpose is to serve as indicators, either for the explorers themselves or for someone else, confirming that they are on the 'right path'.

(print) Papillary prints of an individual obtained through inked impressions on ten-print cards are best described as prints. A print involves the deliberate establishment of a physical reference mark, the source of which is irrevocably or indisputably known. Typically, creating a print involves a commitment to ensuring quality, often necessitating multiple attempts to achieve an acceptable standard for use as reference material.

(Indicant and Print) A biometric recognition system has two different stages: enrolment and recognition. Enrolment consists of acquiring biometric features of an identified person to create a model of this specific identified person. If there is an agreement that enrolment procedure is robust enough, the model saturates the determination of the referent and acts as a print (reference material) within the recognition system. During the recognition stage, biometric features are also extract but from an unknown person. Those newly acquired biometric features are called a probe. A probe is an indicant which is compared to the model (print) and a match score is generated. The match score itself is an indicant of how similar the model and the probe are. In the context of specific verification systems, which are more and more commonly employed and accepted to attest the identity – such as passport controls, ID checks on smartphones (face ID or print ID) –, these match scores may be considered as prints.

#### 3.2.2. What about photography?

In light of these considerations and examples, photography, as an analogical view resulting from a photonic recording of a trace, derives from a deliberate communicative act initiated by an operator. It should be noted that surveillance camera images recorded automatically without human intervention may initially appear as an exception. However, the intentional codification of specific staging by an operator should not be mistaken with the communicative act itself. A photograph inherently exists to function as a sign, regardless of whether it undergoes additional codification by an operator. In this sense, photography unequivocally represents a communicative act: an indicant.

Nonetheless, in forensic science, many photographs, like Bertillon's signaletic photography, which gave rise to the mug shot, transcend the realm of mere indicants. Signaletic photography involves a photonic recording (*trace*) stemming from a deliberate communicative act (*indicant*) whose source and meaning are established by convention in the context of its use (*print*). Thanks to its rigorous acquisition protocol, such images are regarded as objective representations of individuals whose identity is known, thus serving the purpose of recognition. These forensic photographs essentially fall under the category of reference material, a characteristic aligning with the notion of a *print*.

#### 4. The trichotomy of the trace

As previously discussed, we distinguished three "semiotic objects" of the real world: the trace, the indicant, and the print. In the following explanation, we will elaborate on how these objects are situated within the three different semiotic hierarchical categories of being.

Before delving in this theoretical elaboration, it is essential to make two fundamental clarifications. Firstly, the term trace is defined exclusively in relation to its actual referent. Accordingly, our semiotic analysis is limited to the indexical sign, whereby the referent of the trace (the external world) corresponds to the object of the sign (the interpreter's internal world). The smoke, a remnant of a fire, is a sign of that fire. As a trace, it provides information about the fire, but it does not signify anything yet. For example, as a trace, smoke is not a sign of danger. The signification of danger is an accretion of the interpretant to a symbol during semiosis, which is beyond the scope of our discussion.

Secondly, by focusing our attention solely on the result, the vestige of something, in the context of the reception of the sign by an interpreter, these three objects cannot be differentiated and correspond in every respect to Margot's definition of the trace. Once created, the result is a physical remnant of something that has a real existence. A trace, remnant of something, is second as "*secondness is the category of reaction, opposition, differentiation, existence [...] it consists in one thing acting upon another*" (CP 8.330). However, the physical result is not the only way to consider a trace. To differentiate between them, it is essential to consider the context in which the sign was emitted and to focus on the process of production rather than the result. At this stage, the vestige does not yet exist and is purely potential. It should be noted that not all aspects of the vestige's mode of production are decisive in differentiating these three types of objects. The crucial factor is whether the formation of the vestige is a straightforward, pure physical consequence or whether it is shaped by a communicative intent on the part of the sender and/or operator. This study proposes a fundamental distinction between smoke, a straightforward and pure physical consequence of combustion, and smoke signals, one of the earliest forms of long-distance communication. The fundamental differentiation lies not in the outcome, as smoke remains a tangible consequence of fire in both instances, but in the intricate construction of the signal, shaped by the communicative intent of the operator.

##### 4.1. Trace

A trace is "*essentially involuntary*" ([17], p. 81). Considering its production process, a trace is an *authentic and pure* physical remnant of something. In this context, the terms "authentic and pure" are used to describe an *automatic* production devoid of any communicative intent that might have shaped its fabrication. At the stage of its genesis, a trace is just a possibility and is not influenced by a communicative intent from the emitter/operator. It is just what it is regardless of anything else.

According to Peirce's perspective, the genesis of a trace is first as "*firstness is the mode of being which consists in subjects' s being positively such as it is regardless of anything else*" (CP 1.25). A trace does not inherently possess semiotic intentions from an emitter that shaped its fabrication.

Building upon the insights of the  $\mu$  group ([9], p. 132), we can define

the *global reference model*  $\mathbb{R}$  as encompassing all elements involved automatically in the production of a trace (including people, instruments, and so forth) and the *trace*  $T$  produced by  $\mathbb{R}$  at a specific moment  $t_0$ . Since  $T$  is distinct from  $\mathbb{R}$ , some transformations  $\Delta R$  occur during the production of the trace  $T$ . In the case of the trace, the feature comprising  $T$  originates from the global referential context  $\mathbb{R}$  at the time of its production  $t_0$ . The production of the trace can be conceptualised as illustrated in Fig. 1.

In light of the firstness of its genesis and the secondness of its outcome, a trace, vestige of something, is a "*fundamental vector of information that is capable of being detected, recovered, examined and interpreted*" [25].

##### 4.2. Indicant

The indicant is second as its semiotic qualities possess real existence at the core of its genesis. The indicant is inherently imbued with communicative intention, signifying its purpose as a sign of something. The indicant exists intrinsically to be a sign. From this hierarchical perspective, as a second, an indicant requires a trace. Without a trace, an authentic and pure vestige of something, the indicant does not exist as an index.

Considering the secondness of its genesis shaped by an effective communicative intent, an indicant is a vector of a message about its referent from an emitter/operator to a receiver in a circular communicative process.

Following the structure introduced in Fig. 1, we should incorporate within its production model the global producer model  $\mathbb{P}$  and the indicant  $I$ , stemming from the intrinsic voluntary act.  $\mathbb{P}$  should be regarded as encompassing the human operator and the tools employed in its voluntary communicative creation. Consequently, the indicant comprises two hierarchical layers: one corresponding to the trace  $T$ , with attributes drawn from  $\mathbb{R}$ , and the other to the indicant  $I$ , associated with  $\mathbb{P}$ , both undergoing their respective transformations  $\Delta R$  and  $\Delta P$ . The indicant, positioned hierarchically superior, encloses the trace and while asserting its status as an indicant. While transformations introduced by  $\mathbb{P}$  might relate directly to  $\mathbb{R}$ , for the sake of simplifying the representation, we group them under  $I$  and  $\Delta P$ . This representation yields the Fig. 2 below.

The indicant  $I$  possesses characteristics stemming from the referent as well as the producer. Thus, the indicant serves two referential functions: one towards the referent and another towards the producer. Additionally, the proportion of  $T$  and  $I$  within the overall function of the indicant can vary significantly. For instance, a shot caught up spontaneously in the dynamic of an event may have a weaker  $I$  component compared to a meticulously crafted advertising image, while both maintain their hierarchical indicant status. Lastly, an interpreter will perceive the indicant as a composite of the two layers,  $I$  and  $T$ . Whether the interpreter can distinguish  $I$  from  $T$  and accurately attribute them to  $\mathbb{R}$  and  $\mathbb{P}$  respectively depends largely on the interpreter and his/her contextual knowledge.

Since the genesis of the indicant is second, it can be authentic or degenerate. An indicant is considered authentic when it results from a conscious choice or communicative decision by a producer in relation to a specific referent. Consequently, a photograph is an authentic indicant since it is a deliberate *artefact* of the operator. Conversely, an indicant is degenerate when it does not directly result from the producer's choice but originates from external factors not necessarily related to the specific

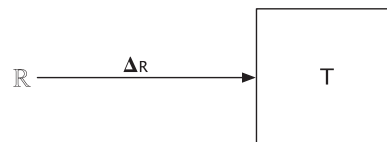


Fig. 1. The production of the trace at  $t_0$ .

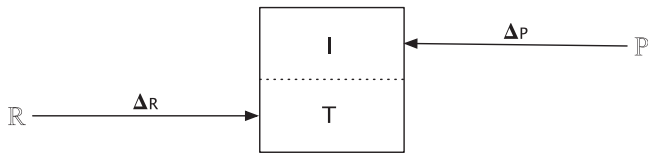


Fig. 2. The production of the indicant at  $t_0$ .

referential context. For instance, while a photograph, as a voluntary recording of a trace signal, is authentic, the metadata automatically embedded by a digital camera within the computer file are degenerate indicants. This metadata does not result from the operator’s choice but are established by the manufacturer, typically based on established standards. This metadata, like all digital domain-related computer logs, constitutes degenerate semiotic indicants. They are created to convey meaning, but this signification, voluntarily established by someone else, is not the operator’s choice within the referential activity.

### 4.3. Print

The print is third in Peirce’s hierarchy as its semiotic attributes are further bolstered by conventions or habits saturating the determination of its referent for an interpreter. The print does not only exist intrinsically to be a sign, it also bears an established, conventional determination pertaining to its referent. It exists as a conventional sign in the external world which saturates the referent determination. As a third, the print exercises its hierarchical status, necessitating both indicant and trace.

Considering the thirdness of its genesis shaped by an effective conventional communicative intent, a print is a vector of a conventional message about its referent from an emitter/operator to a receiver in a circular communicative process. This conventional message saturates the determination of its referent which enables its consideration as reference material.

Keeping the same formal framework as previously outlined, Fig. 3 illustrates the print’s production at  $t_0$ . An institutional convention  $C$ , which undergoes the transformations  $\Delta C$ , exerts influence on the comprehensive object by introducing an additional Print layer, denoted as  $S$ . The conventional set  $C$  potentially encompasses a part of the producer set  $P$ , but only to the extent that the producer acts within the fixed framework of the conventional context. Any deviations made by the producer infusing personal elements are expressed within  $I$ , influenced by  $P$ .

The print assumes three distinct referential functions: the referent, the producer, and the convention. The prevalence of these functions varies across different signs, but the hierarchical structure confers the status of print upon it. To function as a print, it tends to impose the conventional attributes determined by  $C$  on the overall composition while simultaneously minimising uncertainties arising from involuntary traces ( $T$ ) of the referent and the voluntary contributions of the producer ( $P$ ). Finally, to be acknowledged as a print, both the producer and the interpreter must share common institutional conventions.

### 5. Towards a refined definition of the trace

A photograph, belonging to the interpreter’s external world, is a particular object, which differs from a trace by its inherent

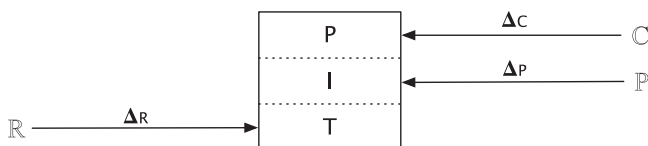


Fig. 3. The production of the print at  $t_0$ .

communicative intent. In contrast to the trace, which is an involuntary outcome, the photograph is purposefully created to deliver a message for someone about its referent.

First, a trace is an authentic and pure remnant of something being generated *automatically* and has a relationship of physical contiguity with its referent. It is a simple physical consequence of something. Second, an indicant inherently holds a communicative intent that shapes its production; it exists to convey a message. Considering its emission process, photography is an *artefact* stemming from the communicative intent of an operator. It aims to deliver a message about its referent to someone within a circulatory process. Therefore, from this perspective, despite its indexical essence, photography cannot be considered strictly as a trace but rather an indicant. Third, a print conveys a conventional message, which saturates the determination of its referent to act as reference material. This convention is elaborated and inscribed in the very process of production. These three entities within the external world establish a novel triadic hierarchy, comprising the trace, the indicant, and the print.

In light of this triadic hierarchy and our comprehensive analysis about photography, we propose a refined adaptation of Margot’s definition of the trace. "Signal, object or mark, a trace is an authentic and pure remnant of a past or ongoing presence, action or alteration with which it has some physical contiguity. Detected and considered as a sign by an interpreter, a trace is a fundamental vector of information about its object.

The formulation has been refined through the implementation of several key lessons learned from our this paper:

- The importance of knowledge about the genesis of the trace: the mode of production defines the essence of the trace and is complementary to its observable result or factual state.
- The inherent automatic involuntary nature of a trace: a trace is an authentic and pure remnant of something. It has no intrinsic communicative intent that shapes its creation and becomes a sign only when interpreted.
- The importance of the signal in an increasingly digitised world. In such an environment, materiality is expressed through physical components like microchips, transistors, wires, and storage devices. These physical components interact with electrical or optical signals to process, store, and transmit data. These signals are typically in the form of digital data that encodes various types of information, such as text, images, audio, and more.
- As a remnant, a trace is invariably oriented towards the past, even when this past may be almost contemporaneous with the present.
- The spatiality and temporality of the trace itself and in relation to its referent depends respectively on its own materiality and their physical contiguity. A signal can be very ephemeral, whereas a mark can exist for a long time. Some traces require a physical contact with its referent while others need some distance. In a digitised world, these relationships, based on the physical contiguity of the trace with its referent, have become more complicated and less straightforward.

### 6. Conclusion

The reflections carried out in this paper have led us to determine a model describing the nature and pragmatic functioning of the photographic sign.

For an interpreter, a photograph (external world) is a sign (internal world) that stands for its referent, not in every aspect, but by reference to certain qualities of the referent. More precisely, the photograph is a trace of a signal emitted by a referent. From a semiotic point of view, for an interpreter familiar with the automatic nature of its genesis, it is an index: a sign that has a real occurrence and that has a relationship of physical contiguity with its referent, which has also a real existence.

The trace, which corresponds to the analytical measurement of the optical image formed on the photosensitive medium, serves as the primary informational foundation for the image: the *photonic image*. When



an interpreter recognises its indexical nature, it is accompanied by the recognition of the four principles of individuality, unity, attestation of existence, and designation. At this stage, the photographic image signifies nothing other than what follows from these constitutive rules: 'it-is-individual', 'it-is-a-whole', 'it-has-been', 'as-it-was', 'See, here, there'!

However, photography differs from the trace: it is an artefact resulting from the communicative intent of an operator to deliver a message to someone. Photography inherently possesses communicative intentions. It is an indicant that also has a hierarchical relationship with the trace in the Peircian sense. The indicant is distinguished from the trace by its voluntary genesis, the latter not being born to signify something. The trace, arising from its automatic genesis, belongs to the category of Firstness. A trace is fundamental vector of information about its referent. The indicant, the voluntary result of an operator, is second: it has semiotic intentions. An indicant delivers a message about its referent for a receiver in a circular communicative process. Likewise, when an established convention saturates the determination of the referent, it could stand as a print. The print is third in Peirce's hierarchy as its semiotic attributes about its referent are conventional. The print not only exists to serve as a sign but also bears a conventional message that saturates the referent determination that enables its consideration as reference material.

These three entities coalesce to constitute a novel hierarchical trichotomy comprising the trace, the indicant, and the print.

Finally, the trichotomy that has emerged from our analysis of the photographic sign enables us to draw broader conclusions and to propose a refined forensic definition of the trace.

#### CRedit authorship contribution statement

**Pierre Margot:** Writing – review & editing, Supervision. **Romain Voisard:** Writing – review & editing, Writing – original draft, Conceptualization.

#### Declaration of Competing Interest

None.

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