Filling with Nothing – An Ontological Analysis of Empty Information

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Abstract

We often think about information as having some kind of substantial content. Texts and their parts (sentences, words, letters…), pictures and musical scores are all substantial in some sense. However, some pieces of information seem to be less substantial, such as a space between two words, a portion of canvas left unpainted, a silence during the performance of a piece of music or a field in a form that is left unfilled. To analyze them, we build on slot mereology applied to informational entities, which introduces two entities: informational slots and informational fillers that may fill those slots. We identify three heterogeneous ways in which one may speak of "empty" information: first, a concretization of information that involves some absence, such as an empty pattern or a silent process; second, informational slots that can act as receptacles for fillers; third, empty informational fillers indicating that some information is voluntarily not provided. The introduction of such empty informational fillers makes it possible to satisfy an important axiom of company in slot mereology applied to informational entities.

Keywords

Informational entity, Slot mereology, Absence, Template, Cognitive representation

1. Introduction

We often think about information as having some kind of substantial content. Texts and their parts (sentences, words, letters…), pictures, musical scores, are all substantial in some sense. This is apparent in the fact that typically, information is conveyed by some marks (on a paper, a screen, etc.) – consider e.g. an ink pattern forming the letter "a", the picture of a rabbit, or a musical note. However, there is another kind of important information conveyor, which seems less substantial. Consider e.g. a space in a written text between two words; a portion of canvas on a painting that is left unpainted; a silence during the performance of a musical piece; or a field in a form that is left unfilled. There is no doubt that such features can be relevant. Is there something in common shared by all of them? Because such information is typically represented by some absence rather than a presence, its existence is unclear: are there "empty" pieces of information? Or should we refrain from positing the existence of absent information as an entity? And more fundamentally, what does it mean for a piece of information to be "empty"? A particularly important example of empty informational entities concerns relational databases, namely the NULL value. In electronic health records, for example, absent data points (that is, data generated during a procedure but that are not present in a data source) are a pervasive and complex phenomenon to deal with. Finding ontological correlates of such values is important when using e.g. ontologies associated with such records (such as ontologies of drug prescriptions PDRO [1] or laboratory tests LABO [2]) and matching them with a relational database structure [3].

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This paper will thus argue that it is important to distinguish and represent at least several kinds of empty information[2] in ontologies. In particular, it will distinguish 1) "empty representations" (or, more technically, "empty concretizations" of some informational entities), where it is the physical trace or process materializing the informational entity that has some empty dimension (absence of a mark, of a sound, etc.) from 2) some inherently empty informational entities, encompassing in particular: 2-a) slots that determine the mereological structure of an informational entity, and 2-b) "empty informational fillers" that specify that the information that is expected to be indicated in such a slot is not provided. This analysis will clarify the philosophical status of informational slots that were introduced in former work [4,5], and the introduction of empty informational filler will enable the satisfaction of an axiom of company in slot mereology applied to informational entities.

The next section will present some philosophical work on nothingness and emptiness. The third section will expose the motivation and methods, presenting in particular the analysis of informational entities in the Informational Artifact Ontology (IAO) [6] based on BFO [7]. The fourth section will propose an ontological analysis of scenarios that could be informally characterized as involving empty information, and will distinguish three different kinds of such "emptiness" as explained above: empty concretizations, informational slots and empty informational fillers. The fifth section will show how the introduction of some empty informational fillers enables to satisfy an important axiom of company in slot mereology applied to informational entities. A sixth section will conclude the paper.

2. Philosophical and ontological work on nothingness and emptiness

A first field of study that is important to distinguish from our present topic of interest is the philosophical study of nothingness. It will be helpful though to say a few words on this topic. Parmenides famously argued that "nothing" cannot exist: one can only speak of a thing that exists. From this, he deduced the impossibility of change: we cannot speak of a thing in the past (as it does not exist anymore), and thus the supposed change from a thing in the past to a thing now does not exist. For Heidegger, the fundamental question of metaphysics was "Why are there beings at all, instead of Nothing?" [8].

A related branch of philosophy is "meontology", namely the branch of philosophy that study non-existence. Philosophy is replete with ontological deflationist theses: idealism claims the inexistence of the material world (*pace* the materialists), nominalism claims the inexistence of universals (*pace* the realists about universals), illusionism denies the existence of consciousness (*pace* Descartes), mathematical anti-platonism denies the existence of mathematical objects, etc.

Our focus of interest here will be, in a sense, the opposite: where some philosophers claim that some things that "obviously" seem to exist (such as the material world or consciousness) do not in fact exist, we will claim that some things that might seem not to exist – namely, empty information – do, in fact, exist. As often in applied ontology (but also sometimes in philosophy [9]), our argument will be practically guided: we will show the usefulness of ontologies that assume the existence of empty information – and leave open the question of how those practical considerations should influence a *bona fide* philosophical ontology of the world.

Some forms of Buddhism allow *Śūnyatā* (emptiness) [10] – by contrast to "nothingness". More recently, Casati and Varzi proposed an ontology of holes [11] and Hahnmann and Brodaric an ontology of voids [12]. Thus, our position will find place in this tradition that gives an ontological status to apparently empty entities, in the specific context of empty information. What is the status of e.g. a space character in a text, a silence in an utterance, a blank portion of canvas or an unfilled field in a form? As we will argue, it will be useful to give an ontological status to "empty information", but we will show that this informal term can encompass ontologically heterogeneous categories.

[2] In this paper, "empty information" should be understood as a shorthand for "empty informational entities" or "empty concretizations of informational entities" (as will be clarified later), and should not be interpreted as zero-information messages conveyed by logical tautologies in the context of Shannon's theory of information.

3. Background and Methods

3.1. Background: Empty Information and its Meaning

By separating chains of characters into words, space characters play naturally a role in the meaning that we can assign to a given text: "xxxyyy" and "xxx yyy" will typically not be understood the same way. Moreover, whether we admit its existence in a strong sense or not, so-called "empty information" can certainly carry meaning thanks to the pragmatics of communication – consider e.g. the following dialogue: "How do you like my new shirt?" "It's… [long pause][3] interesting…" Think about a silence in a musical symphony: an instrument that stops playing, or a plain, total silence. Such silences can typically carry meanings of quietness; a feeling of achievement – or, on the opposite, of expectation; embarrassment; anxiety; trouble; death; and so on.

Calligrams by Apollinaire [14] are poems where letters and spaces are arranged to represent common shapes, such as a bird or a fountain; such spaces might be seen as empty informational units that act as building blocks for shape depiction. The painting *White on White* (1918) by Malevich raises the issue of the status of a white portion on a painting, where the contrast between two kinds of whites might evoke floating, infinity or movement. Relatedly, the play *Art* by Yasmina Reza [15] questions the artistic value of a canvas painted in white. However, ontologically speaking, a portion of canvas painted in white is not so different from a portion of canvas painted in blue or red – although it may make an important artistic or psychological difference. More relevant for our current discussion is a portion of canvas left unpainted on a painting, which may certainly carry meaning (a message, an emotion…) at some level – whatever our theory of meaning of art is. In traditional Chinese and Japanese art, "yohaku" refers to the use of empty space: blank spaces were considered to play an important role in the composition, and to be as important as painted spaces. It could represent light or pictorial depth, concrete entities like snow, or more abstract notions such as emptiness or time flow [16].

On the musical side, John Cage realized a full piece of music of total silence[4] named *4'33"* [17] – that was "performed" on some occasions. If there is no such thing as a musical silence, then one would have to conclude that he did not create anything with this work; he certainly thought differently.

If empty information can carry meaning, it is only a small step to suppose that there might indeed exist pieces of empty information that are about something, and in linguistic terms have a syntactic, a semantic, or a pragmatic role (see e.g. the null subject phenomenon [18]). The conveyor of information in such situations might not be empty information though, but a more general entity that encompasses this apparent empty information. For example, in the dialogue mentioned above, the doubt about the shirt might not be carried by the silence by itself, but by the whole dialogue encompassing the silence. As we will see though, it will be useful to posit the existence of such empty information.

Note that if empty information exists, then there is arguably not only one *instance* of empty information, not even only one *type* of empty information: the space in a written text, the blank on a painting canvas or a box on a form left empty are all different kinds of information. I cannot use a musical silence on a painting; I cannot move a space that appears between two words to a musical score between two notes. Those kinds of information have very different nature.

3.2. Methods

A variety of ontological frameworks have analyzed the status of informational entity [19], with a focus on "substantial" informational entities, such as words, sentences or figures. We will show how such empty information can fit in the theory of information content entities in the context of BFO and IAO, with occasional inputs from other ontologies.

[3] We consider here the case where this pause is an authentic silence, but in real life, such "pauses" are often filled with sounds such as "er" [13]

[4] Although according to John Cage, the environmental sounds that are thereof heard during its performance are supposed to be part of this performance.

3.2.1. Representations and Information Content Entities in IAO

The entities used in this paper are represented on figure 1. In particular, all the axioms reflecting the taxonomic structure will be accepted, that is, if A is a subclass of B, we accept Aa → Ba.

In BFO, dependent continuants are divided into specifically dependent continuant (SDC, that inhere in a specific independent continuant) and generically dependent continuant (GDC, that "can migrate from one bearer to another through a process of copying" [[7] p. 179]). An important subclass of SDC is *Quality*. The Information Artifact Ontology (IAO) [6] introduces the class *Information Content Entity* (ICE) as a subclass of *GDC*: documents, databases, paintings, etc. ICEs are about some "portion of reality", a label which encompasses all the BFO particular entities (including ICEs) but also universals, relations, and "configurations" (e.g., the cat being on the mat). ICEs can be "concretized" by one (or several) "information quality entity" (IQE), but also by one (or several) processes (e.g. an utterance or a music performance) since BFO-2020 [20].

Smith & Ceusters [6] define *Representation* as "a quality which is about or is intended to be about a portion of reality". Where an ICE must be about some portion of reality, a representation is "more comprehensive in scope": it can intend to be about something without actually being about something (in BFO's acceptance, which only admits entities recognized by science) – such as a unicorn drawing by a child who believes that unicorns exist.

The mental functioning ontology further defines *Mental quality* as "a quality which specifically depends on an anatomical structure in the cognitive system of an organism" and *Cognitive representation* as "a representation which is a mental quality". Cognitive representations have constituent parts named "representational units".

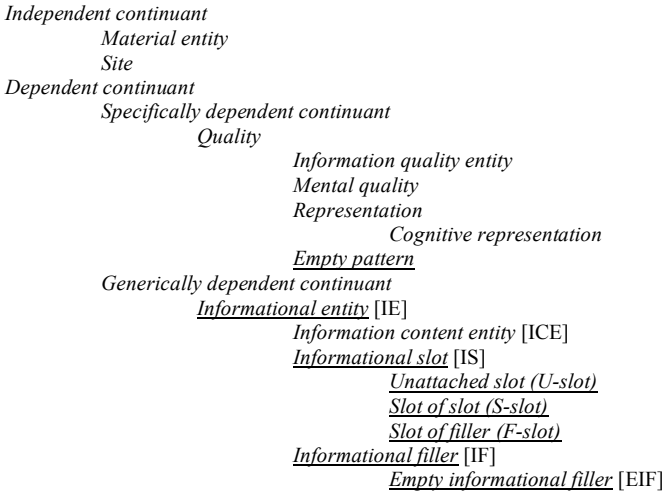

Figure 1: Taxonomies of continuants in BFO and IAO, with classes added by us underlined[5]

IAO then introduces two binary relations. First, "x is_a_representation_of y" means that "x is a representation & x is_about y" (where y is a portion of reality; note that not all representations are about something – consider e.g. the unicorn drawing mentioned above). Second, "x is_conformant_to y" means that "x is an information quality entity & y is a cognitive representation & there is some GDC g such that x concretizes g and y concretizes g." For example, if John has a cognitive representation y of some configuration and writes a concretization x on a piece of paper reflecting this representation (and thus describing this configuration), then there is an ICE g concretized by both x and y, such that x is conformant to y.

[5] *Cognitive representation* is also a subclass of *Mental quality*. IE, IS (and its subclasses) and IF are introduced in former works [4,5].

3.2.2. Proposed Extension of IAO

To account for the fact that some informational entities (such as letters) are not about anything, contrarily to ICEs, but may be building blocks of ICEs, Barton et al. [4] introduced the class *Informational entity* (IE) – which can be elucidated as "A GDC that is a building block of information or a combination of such building blocks". For example, the word 'cat' (which is an ICE) is an IE, but so are the letters 'c', 'a' and 't' (which are arguably not about anything and thus not ICEs). ICEs are concretized by qualities (although those are not always IQEs, which by definition can only concretize ICEs). Like ICEs, informational entities can be concretized by mental qualities – although those qualities are by definition not cognitive representations when they concretize an IE which is not about anything. Note that we can also easily extend IAO's notion of conformance to concretizations of such informational entities that are not necessarily about anything, by introducing the relation "x is_conformant^{+}_to y" meaning that "x concretizes an *informational entity* & y is a *mental quality* & there is some GDC g such that x concretizes g and y concretizes g."

A first step towards empty information has been made by some former work on the ontology of information templates [4,5]. Such templates can be filled with information content entities, but are considered to exist even if unfilled: think for example of a Latex template, which is an entity in its own right. A template has some "empty" dimension (even if it can of course be constituted by very substantial computer language), in the sense that it is a receptacle for more substantial information, typically a document.

Informational slots have been introduced [4] to account for the fact that an informational entity can have several times the same informational entity as part, something impossible in classical mereology. For example, the string 'the cat'[6] has as part twice the letter 't'. Substantial informational entities such as 'the cat' or 't' are called "informational fillers". Their mereological structure can be described by slots, more precisely, "F-slots" [5] or "slots of fillers", where a slot is linked to its owner by the relation "slot-of" (S). Fillers can then fill slots themselves by the relation "fills" (F)[7]. For example, the string filler 'the cat' has several F-slots, two of which are filled by the same filler 't'. The mereological relation of parthood is analyzed in terms of the relations S and F: a filler x is a direct proper part of the filler y iff x fills an F-slot of y. Thus, the string 'the cat' has the letter 't' as part twice. More generally, any part of an informational entity occupies a slot of that informational entity – so there exists also, for example, a slot for 'the' and a slot for 'cat' in 'the cat'.

Not only fillers can have slots though. In particular, templates are composed by informational slots, that are also receptacles for proper parts of the document. Because they are not encompassed into something bigger, templates[8] are called "unattached slots" (U-slots), and the slots that compose them (for example a field for a first name or an address) are called "slots of slots" (S-slots), and related to their slot-owners by the same relation S [5]. Thus, slot mereology is an important tool for both the mereological structure of documents and templates.

Slot of slots can be related to their slot-owner by two subrelations of S: mandatory-slot-of (MS) and optional-slot-of (OS). Mandatory slots of a slot must be filled for this slot to be filled; but a slot can be filled without all its optional slots being filled. For example, a slot for an American full name would have a slot for the last name and a slot for the first name that *must* be filled for the full name slot to be filled, and a slot for middle name that *may* be filled. The two formers are mandatory, the latter is optional.

It is important for any ontology to analyze the ontological nature of the entities it introduces, typically by characterizing it pre-formally in a first step. We should not introduce entities motivated only by their formal convenience (contrast with other work on void entities [12], which introduces a "unique zero region of no extent and no location", whose ontological nature seems difficult to characterize). The importance of such a pre-formal analysis should not be underestimated in any authentic ontological analysis of the real world. Thus, this paper will give a specific attention to

[6] Informational entities will be written with single quote marks.

[7] In this paper, "filled" should be understood as "adequately filled" in the sense defined in [21]: structurally adequate (the filler has the right structure as constrained by the slot it fills), semantically adequate (the filler is about the right sort of things as expected by the slot it fills) and descriptively adequate (the filler describes a configuration of the world that obtains) when applicable.

[8] Here, we call "template" strictly the entity composed by various fields, not the informational entities that might help to read and use this template (such as boxes encompassing those fields, labels of those fields, etc.)

characterize precisely the real correlates in the world of the formal elements of the theory, which might be especially difficult to pinpoint when dealing with "empty" informational entities.

4. Ontological Analysis of Scenarios Involving Empty Information

We will now provide an ontological analysis of two sets of scenarios involving seemingly empty information. The first set (section 4.1) will concern space in a text, a canvas left blank and a silence in a musical piece. The second set (section 4.2) will concern fields in a form. We will then consider (section 4.3) how adding informational slots to the picture can provide a fuller account of the situation, and introduce (section 4.4) empty informational fillers.

4.1. First Set of Scenarios: Space Character, Blank Canvas and Silence

To clarify the nature of so-called "empty information", we will consider several scenarios presented in Table 1 below (note that T_1-T_3 happen in succession, as well as P_1-P_2 and M_1-M_2). In scenario T_1, there is an ink pattern written by John on a paper that reads 'the cat', which is a representation of (say) his cat Felix, and concretizes a specific ICE. But there is also an informational entity corresponding to the space between 'the' and 'cat', that we will call "IE_T". Thus, IE_T is a part of the first ICE, and we can suppose that both are concretized by mental qualities in John's mind. However, John does not leave any kind of ink mark on the paper to concretize IE_T: he merely takes his pen up at the end of writing "the", moves it to the right, and put it back down to write the word "cat" (assuming he writes them all on the same line). If we suppose that there is a concretization on paper conformant$^+$ to all relevant mental qualities, then there must be a concretization of IE_T on paper. This would be the pattern q_T on the sheet of paper approximately delimitated on its left by the concretization (an ink pattern) of the 'e' of 'the' and on its right by the concretization (another ink pattern) of the 'c' of 'cat'; we can call such a pattern an "empty pattern"[9]. Therefore, the empty pattern q_T is ontologically dependent on the ink patterns (concretizing the 'e' and the 'c') that approximately delimit its shape. Such patterns belong to what DOLCE categorizes as "features" (that also include e.g. edges, bumps, etc.) [22]. Empty patterns that concretize information content entities can thus be called "empty concretizations".

Table 1
First set of scenarios: Text, painting and music

Scenario	Scenario description
T_1	John writes by hand on a paper "the cat".
T_2	After T_1, John reads aloud distinctively the words he wrote "the cat".
T_3	After T_2, John copies the words "the cat" he wrote earlier on a computer using a text editor.
P_1	On a physical painting on which he has been working, John leaves a portion of canvas blank and states his work is finished.
P_2	After P_1, John digitizes his work of art; the portion of blank canvas is represented on a screen by white pixels.
M_1	On a musical score, John leaves a sign between two notes to indicate a silence (a pause between two notes).
M_2	After M_1, the musical score is performed by an orchestra.

[9] A subtle question concerns the difference between such empty patterns and BFO:sites [5], which are independent continuants typically demarcated by material entities and their surrounding medium and "which can thus change location, shape and size as their material hosts move or change shape or size" [20] (such as a grotto or the hold of a ship). It might be the case than such an empty pattern delimitates a site. Note however that if some informational entities could be concretized by sites, there would be a significant heterogeneity between those concretized by qualities (which are specifically dependent continuants) and those concretized by sites (which are independent continuants) – hence the preference for "empty patterns" here. See also the related work on the ontology of holes [11] and voids [12].

In scenario T_2, when John reads aloud distinctively 'the cat', he produces a sequence of sounds, including a pause (no sound) between the sounds concretizing 'the' and the sounds concretizing 'cat' (note that this is the case because he reads the words *distinctively*; in daily life, we often do not make a pause between two pronounced words, in which case the space IE_T is arguably concretized by the non-silent transition between two sounds). The process of this pause is then the concretization of IE_T. Such silences, here again, can be called "empty concretizations".

In scenario T_3, it seems that John copies IE_T on his computer the same way he copies the other, more "substantial" characters such as 't', 'h', 'e', 'c', 'a' and 't': by pressing a key of his keypad. This character is (typically) concretized on the screen by some pixels being lit in white (or black in dark mode), while other characters are typically concretized by some pixels being unlit (or lit in black) and others lit in white. It is also concretized in the memory system of the computer by some bits (or an electronic quality at a finer level of granularity – to put it simply), the same way all characters are concretized. For example, the ASCII code of 'the cat' reads '116 104 101 32 99 97 116', where the space is represented by the code '32', in a similar way to (say) the character 't' being represented by the code '116'. In this scenario, the space IE_T is concretized similarly to more "substantial" characters, contrarily to what happened in scenario T_1 where IE_T was concretized by an empty pattern, whereas other characters were concretized by more substantial ink patterns. As it happens, there is a large variety of "invisible" characters [23] and although their concretizations are sometimes similar (e.g. a series of white pixels), some of their other concretizations are different (e.g. Unicode, "show non-printing characters" mode or bits) and the underlying informational entities are definitely different[10].

Scenario P_1 is to painting what scenario T_1 is to text. One can argue that there is an informational entity IE_P concretized at least by a mental quality in John's cognitive system, which represents the space left unpainted on his canvas. Like IE_T in scenario T_1, we can consider it to be concretized by an empty pattern on the painting (delimitated by neighboring painted areas), which is then conformant$^+$ to John's mental quality. In scenario P_2, the same blank part on the canvas might be concretized in the computer system by some electronic quality (and then concretized on screen, e.g. by white pixels).

Let's now turn to scenario M_1 and M_2. A silence symbol on partition concretizes some information entity IE_M that can be also concretized by a process of abstaining from playing any note[11]. Of course, IE_M would also be concretized by some mental qualities in the cognitive systems of the conductor and the players. Thus, the nature of a silence is not so different from the nature of musical note: it is concretized by some mental quality when read, and it is concretized by (say) some ink pattern on the printed partition in M_1. Its only "empty" aspect is when it is concretized by a process of the instruments playing the score staying silent rather than making sounds – as we can see in M_2.

Let's make a quick summary of what we learned so far from those first examples. Some IEs might be concretized by empty patterns, as illustrated by scenarios T_1 and P_1; and by silent processes, as illustrated by scenarios T_2 and M_2. Those concretizations can be called "empty concretizations". Thus, the apparent "empty" character of some empty informational entities characterizes their concretization rather than those informational entities themselves. Scenarios T_3, P_2 and M_1 show indeed how a space character, a blank part of a painting or a musical pause can be concretized exactly the same way as respectively a letter, a painted portion of a canvas or a musical note. That is, we can have two concretizations of the same IE where one is an empty concretization and the other is a non-empty concretization. Let us now turn to scenarios involving templates and their fields, which will reveal other forms of emptiness that characterize the information itself.

4.2. Second Set of Scenarios: Filling a Form

Consider the scenarios in Table 2 (contrarily to earlier scenarios, F_1-F_4 are alternative possibilities and do not occur in a succession). John is married in scenarios F_1 and F_3, and unmarried in scenarios F_2

[10] There is even a programming language named Whitespace that uses exclusively invisible characters: Space and Tab (and Linefeed). A code in Whitespace looks thus uniformly blank for a human user on a screen, but is quite clearly defined at the computer memory level, very similarly to a code written with 0, 1 and linefeeds.

[11] Alternatively, one may consider that such a silence symbol would *direct* a process of not playing anything – that is, (arguably) directing the absence of an action rather than an action. We will however not investigate in this paper "empty" directive informational entities, and consider more simply that musical informational entities can be directly concretized by processes of performance (see [24] for more details on directive informational entities).

and F_4. In all scenarios, a questionnaire features a box with the legend "tick the box if you are married". Let's call "q_F" the empty pattern that is surrounded by the box. In scenarios F_1 and F_2, John misses reading the question asking him whether he is married or not.

Table 2
Second set of scenarios: Form

F_1	John is married. He misses the question and leaves the box empty inadvertently.
F_2	John is unmarried. He misses the question and leaves the box empty inadvertently.
F_3	John is married. He reads the question and ticks the box by writing an "x" in it.
F_4	John is unmarried. He reads the question and leaves the box empty on purpose.

In scenarios F_1 and F_2, John misses the question. Thus, he does not represent the configuration that he is married or unmarried in the part of his cognitive system that deals with this form (but such an information is concretized elsewhere in his cognitive system, as he probably remembers in some way whether he is married or unmarried). Therefore, there is no informational entity concretized on paper indicating his marital status.

In scenario F_3, when prompted to indicate whether he is married or not, John actively represents in his cognitive system the configuration that he is married by an informational entity IE_{F3}, concretized by the cognitive representation q^{John}_{IEF3}. He then concretizes IE_{F3} on paper by the "x" ink pattern approximately spatially co-localized with q_F that we will call q^{Paper}_{IEF3}.

In scenario F_4, John also actively represents in his cognitive system the configuration that he is unmarried by some informational entity IE_{F4}, concretized by the cognitive representation q^{John}_{IEF4}. Like in the case of text, IE_{F4} would then be concretized by the empty pattern q_F. Since q_F already existed before John started filling the form, this implies that it becomes the concretization of IE_{F4} when John consciously chooses to leave it unfilled[12].

If John did not tick the box, there is no way for an external observer by just looking at the filled form to know whether he is in a scenario F_1/F_2 (that is, John missed reading the question and did not create an informational entity to represent his marital status) or F_4 (that is, John left the box empty on purpose and there is an informational entity IE_{F4}); but if asked later, John can help to clarify whether the situation was F_1/F_2 or F_4. John might e.g. explain that he had not seen this question, or that he had seen this question and left it blank on purpose as he is unmarried. Thus, it is important to be able to represent a scenario like F_4 differently from a scenario like F_1 or F_2. Accepting an informational entity such as IE_{F4} is a way to do so. Like other entities analyzed in former scenarios, however, the empty dimension does not concern IE_{F4} intrinsically, but rather the pattern q_F that concretizes it.

In scenario F_2, the visible status of the form is, by chance, not misleading: although John missed the question, he is unmarried, so the form looks correct to an agent aware of his marital status, and an external reader not previously aware of his marital status is going to make a right inference about John's marital status based on this form. In scenario F_1, on the other hand, the visible status of the form is misleading: an external reader might infer incorrectly from it that John is unmarried. However, from an ontological point of view, the form is incorrectly filled in *both* scenarios F_1 and F_2: indeed, in F_2, for the form to be correctly filled, there should have been a conscious decision to leave the field empty like in F_4 (for more details about the difference between correctly filling and incorrectly filling, see [21]).

Such distinctions have clear applications for clinical documents. Similar to the distinction between scenarios F_1 and F_4, forgetting to fill in your allergy to penicillin versus leaving the relevant field empty

[12] Of course, we do not suppose that there is some kind of magical interaction between John and the paper as soon as he decides that he will not tick the box. The fact that such physical entity concretizes such informational entity is just an ontological rephrasing of the cognitive and communicational nature of language and meaning.

because you do not have such allergy can obviously lead to vastly different consequences, and therefore need to be distinguished.

As we are now going to see, slot mereology applied to informational entities introduces another type of entity that needs to be analyzed: informational slots.

4.3. Refining the Analysis with Informational Slots

The informational entities IE_T, IE_P, IE_M, IE_{F3}, IE_{F4} presented above belong to the class of informational fillers. However, as explained earlier, there is another kind of informational entity, namely informational slots. For example, the string 'the cat' comprises seven F-slots s_1-s_7, filled respectively by the informational entities 't', 'h', 'e', ' ', 'c', 'a' and 't'. If a painting is digitally represented as an array of pixels, each pixel can also be represented as concretizing an informational entity filling an F-slot. Finally, a form is an especially important case of application of informational slots. In scenarios F_1-F_4, the whole questionnaire template would comprise various S-slots: the one that interests us and that can be filled to indicate a marital status of "married", but also e.g. one for the first name, one for the last name, etc.

If we take a broadly realist stance towards ontology, then slots should appear in reality; and if they are bona fide informational entities, they should be concretized. How are such slots concretized? In 'the cat', the slot s_2, for example, which is filled by the letter 'h', might be concretized on the paper by the empty pattern between the concretization of the first 't' and the concretization of the 'e'. Thus, informational slots might also be concretized by empty patterns. But what about the concretization of the slots s_4 filled by the space ' '? Arguably, the empty pattern q_T between the letters 'e' and 'c' concretizes the slot s_4. Thus, if we also accept as explained earlier that q_T does concretize the space character IE_T, it means that it concretizes *both* s_4 and its filler IE_T.

Similarly, on the form in scenarios F_1-F_4, the slot IS_F for indicating the marital status is concretized by the empty pattern q_F. If we accept that an empty pattern can also concretize an informational filler, then q_F concretizes *both* IS_F and the information filler IE_{F4} indicating that John is unmarried in scenario F_4. In scenarios F_1 and F_2, however, where John did not create an empty informational entity concerning his marital status, q_F only concretizes the (unfilled) S-slot IS_F.

Within this framework, we have thus a duplication of "empty" informational entities: the slot IS_F is always concretized in scenarios F_1-F_4 (by the empty pattern q_F on paper in all four scenarios, and by a cognitive representation of John in scenarios F_3 and F_4), and an information filler is also concretized (by a different cognitive representation and the same empty pattern q_F on paper) in scenario F_4. Although it might seem at first sight an expensive ontological price to pay, this ontology enables the differentiation of scenarios F_1/F_2 from scenario F_4, which is important for the reasons explained above. Also, this ontology enables to have an external representation on paper of the filler that is conformant$^+$ to the mental quality concretizing this filler.

Figure 2 presents some of the entities involved in each scenario (instantiated classes are written in italics below the instance names). To represent the difference between scenarios F_1 and F_2, one would need to represent the married or unmarried status of John, as well as the true or false beliefs [25] of the readers of the form: in F_2, a reader may have a true belief that John is unmarried, whereas in F_1, a reader may have a false belief that John is unmarried.

Similarly, all kinds of slots (U-slots, S-slots and F-slots) can be concretized, in particulars by empty patterns. We could imagine other kinds of concretizations: when Jane asks to John "Are you married?", she arguably concretizes a slot for John to provide his answer, and the concretization is a process of her staying silent after asking the question. Note however that slots might be concretized in a more substantial way. A slot for inputing one's marital status, for example, might be represented in a computer in a quite similar way as any filler – namely by a sequence of bits or an electronic configuration. Here again, there is an "empty" dimension we might spontaneously assign to some slots that rather characterize some of their concretizations. However, all slots still have inherently another fundamental "empty" (or "hollow") dimension, namely their status of possible receptacles of fillers.

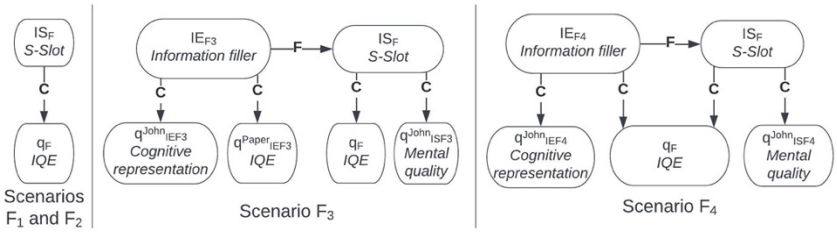

Figure 2: Informational entities and their concretizations in each scenario (C: concretized_by)

4.4. Empty informational fillers

Finally, we need to introduce a third important kind of "empty" dimension. This one characterizes directly some informational fillers, namely fillers that indicate that the information expected to be provided in a slot is not provided, whatever the reason – e.g. because a question does not apply to the respondent, because he doesn't know the answer, or because he does not want to answer it[13]. We will call such entities "empty fillers". Consider for example a form with a slot for the respondent to indicate his middle name, should he have one. It might be filled either by a chain of characters constituting the middle name of the person, or by an empty filler indicating that no middle name is provided – which is not the same as indicating that the person has a middle name, and that their middle name is a chain of blank characters (in that very hypothetical case, the filler would not be intrinsically empty, only its concretization might be). If a field of a form is filled and the answer is then erased for confidentiality reasons, then the original (non-empty) filler is replaced by an empty filler indicating that the expected information is not provided (anymore). To take another example, the missing part of the book that I am writing could correspond to an empty filler filling a slot of the template of my book that is concretized in my cognitive system.

In scenarios F_1 and F_2 above, John did not fill the slot corresponding to the box; in scenario F_3, he filled it with a (non-empty) informational filler concretized by an "x" sign; and in scenario F_4, he also filled it with a non-empty informational filler (since it does provide information), which is concretized by an empty concretization.

We could imagine additional scenarios to F_1-F_4 to clarify further the distinction between empty and non-empty informational fillers. For example, John might be married but deceptively decides to leave the box unchecked. Depending on what he plans to say, should he be confronted about his answer ("I am married but I did not see the field" or "I am unmarried and this is why I left the box unchecked"), he either left the slot unfilled (a case of inadequate filling [21]), or filled the slot with a filler that has an empty concretization and misrepresents reality (since in this latter case he deceptively communicated that he is unmarried); note that in this case, like in F_4, this filler is not an empty filler (since it does aim at providing information). Alternatively, John might not know whether he is married, e.g. if he suffers from dementia; in such a case, he might fill the slot with an empty informational filler indicating that the information is voluntarily not provided (because he does not have access to this information himself). Or he might refuse to communicate whether he is married: here again, he would fill the slot with an empty informational filler.

Of course, we might not know whether John missed the field or saw it, whether he intended to tell the truth or intended to lie, and whether he has access to the relevant information or not – to take a few examples. Nevertheless, as soon as John represents something in his cognitive system, the associated informational entities exist and it is thus important for an ontological theory to be able to account for them. In case the ontologist does not know whether John represented such entities in his cognitive system, he can just abstain from representing the relevant particulars, since ontologies are traditionally written following the open-world assumption. Should John clarify his position, the ontologist could then introduce in the ontology the representation of the relevant particulars. Being able to represent such entities can in itself be a useful guide to design better forms that are able to more effectively capture these different situations.

[13] Note that IE_{F4} above was *not* an empty information filler in this sense, as it did answer the question, by stating that John is not married; only its concretization could be said to be "empty".

An important case of empty filler for information systems is the NULL value in relational database. A problem with NULL is its ambiguity: in particular, it might denote non-applicability of the information (the "nonexistent interpretation") or unknowability (the "unknown interpretation") [26]. An ontology of empty fillers could thus introduce several subclasses of the class *Empty filler*, bringing additional semantics. Such subclasses would encompass respectively empty fillers denoting non-applicability of the information (that is, inexistence of the entity that is supposed to be referred to by the filler of a slot), or those denoting unknowability, or – in the context of relational databases – other aspects as listed on [27]. Thus, an instance of *Empty filler* might be later reclassified into one of its subclasses, should additional information be provided (as in some examples considered in our paper). More specifically, our theory is expected to provide the semantics supporting mappings between a relational database that accepts NULL value and an ontology of information including such subclasses of *Empty filler*. Even further, it can support the creation of relational databases on the basis of this ontology that enables to clarify, for each occurrence of the NULL value, which interpretation of it should be retained (or clarify that we do not know which interpretation of it should be retained for some occurrences of NULL). We will now see that the introduction of such empty fillers is also important from a theoretical and technical point of view to satisfy an axiom in slot mereology.

5. Empty Fillers at the Rescue of Informational Slot Mereology

To explain the important role of empty fillers, we need first to remind that although S-slots describe the mereological structure of templates and F-slots describe the mereological structure of fillers, the former might constrain the later. More specifically, the mandatory slot structure of a slot should be mirrored in the slot structure of the filler that fills it [5]. So for example, if a slot **full_name$_0$[]** has as mandatory S-slots **first_name$_0$[]** and **last_name$_0$[]**, then a filler of it (say 'John Doe') must have a similar mereological slot-structure with two "mirrored" F-slots (say "**first_name$_{JS}$[]**" and "**last_name$_{JS}$[]**"), such that an S-slot and its mirrored F-slot must be filled by the same filler. However, this kind of constraint only holds for the mandatory slots: if **full_name$_0$[]** has as optional slot **middle_name$_0$[]**, then it is not compulsory for a filler of **full_name$_0$[]** to have a mirrored slot of **middle_name$_0$[]** (and indeed, 'John Doe' has no part that would be a middle name – see Figure 3 for an illustration).

Such a representation raises an issue though. Consider now the case of Afghan names, that *must* each contain a first name and *can*, but must not, contain a last name – as not all Afghan persons have a last name. This means that a template for Afghan names **Af_full_name$_0$[]** would have two slots: a mandatory slot **Af_first_name$_0$[]** and an optional slot **Af_last_name$_0$[]**. Consider now an Afghan person named 'Ali' who doesn't have any last name, and let's write x his complete name (see Figure 4a). x fills **Af_full_name$_0$[]**, thus the mandatory slot structure of **Af_full_name$_0$[]** must be mirrored in x: x has a mirrored slot of **Af_first_name$_0$[]** that we will call **First_name$_{Ali}$[]**. However, there is no other F-slot in x: this violates an important "axiom of company" according to which any F-slot of an entity should be accompanied by another F-slot[14]. Such an axiom is especially important, as its violation implies the violations of axioms of weak (and strong) slot supplementation [28].

[14] Note that the classical mereological axiom of company, according to which any proper part of an entity should be accompanied by a different proper part, is not true in slot mereology: the string 'xx' has 'x' as proper part, but there is no informational filler different from 'x' that is a part of 'xx'; however 'xx' has two different F-slots, each filled with 'x'.

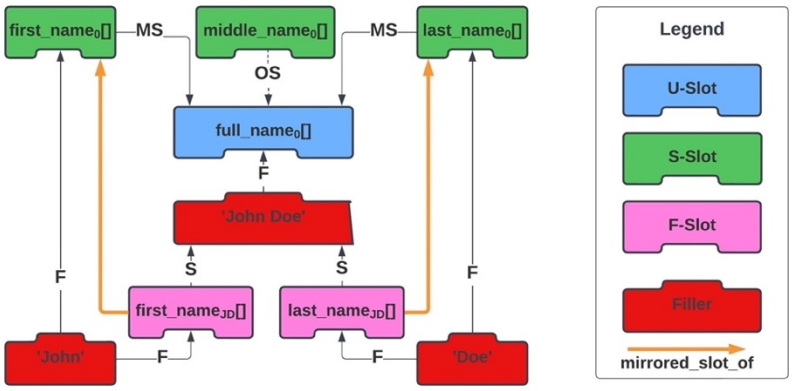

Figure 3: The mirroring of the slot structure of a slot into the slot structure of its filler

Empty fillers offer a way out of this problem. In the former axiomatic system [5], if a slot is filled, then all its mandatory slots are also filled:

(A13) **Mandatory slots of a filled slot are also filled** $\exists y\, Fyt \rightarrow \forall u\, (MSut \rightarrow \exists x\, Fxu)$

We can instead impose that *all slots* of a slot must be filled (for this slot to be filled), but optional slots can be filled by an empty filler. Thus, we replace A13 by the following:

(EA13) **Slot is filled iff all its slots are filled** $\exists y\, Fyt \leftrightarrow \forall u\, (Sut \rightarrow \exists x\, Fxu)$

Of course, EA13 trivially implies A13, but it implies more. First, the optional slots of a filled slot are *also* filled; however, they can be filled by an empty filler. Second, it is sufficient for a slot to be filled that all its slots are filled (keeping in mind that its optional slots might be filled by empty fillers). If we introduce the class "empty informational filler" represented by the predicate EIF, we can also add the axiom:

(EA14) **Fillers of mandatory slots are not empty** $MSut \,\&\, Fyt \,\&\, Fxu \rightarrow \neg EIFx$

This means that we could now impose an axiom according to which all slots of a slot s (not only its mandatory ones) are mirrored by F-slots in the filler of s. In the Ali example, this means that the full name of Ali (let's write it 'Ali ∅'[15]) encompasses not only the information about his first name 'Ali', but also the information that he has no last name (see Figure 4b).

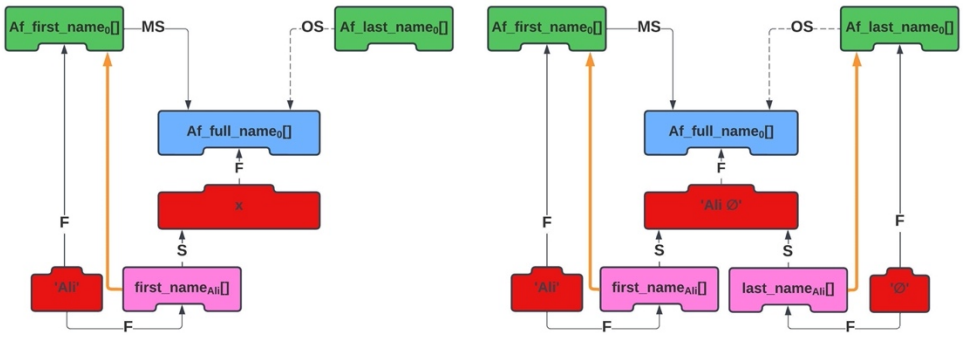

Figure 4: a) Violation of F-slot-company ; b) A reformulation of the theory with empty informational entities

[15] Note that there could be several approaches to the identity of empty fillers. Maybe there is a specific empty filler for a middle name not being applicable, a different one for a last name not being applicable, etc. A more radical approach would be to assume that there is a unique empty filler denoting non-applicability, whose meaning is contextually determined by the slot it fills (synonym to: 'the information expected in this slot is not applicable'). This question would need to be addressed within a wider analysis of the identity of informational entities. In any case, it is important to realize that would two persons named "Ali" fill the last-name slot with the same empty filler indicating non-applicability, the fact that they use the same empty filler would not imply that they have the same last name; rather, it implies that both indicate they do not have a last name.

6. Conclusion

We have identified three heterogenous ways in which an information-related entity can be informally qualified as "empty". First, some *concretizations* of informational entities (whether fillers or slots) are empty in the sense that they are empty patterns or (partial) silence processes, by contrast to more "substantial" entities such as ink patterns or non-silent processes. However, the same informational entity can be concretized by either empty or more substantial concretizations, for example digitally by a sequence of bits or an electronic configuration; thus, this does not characterize inherently empty information. Second, informational slots themselves might be qualified as "empty" in the sense that they can be receptacles of informational fillers. Third, some informational fillers are empty in the sense that they indicate that the expected information is not provided – such as an empty filler of a slot for middle name indicating that the person who filled the form does not have a middle name, or does not want to communicate it. NULL values in relational databases are such a case of empty informational fillers, and introducing subclasses of empty informational fillers might help to clarify the signification of various NULL values.

Note that some concretizations of informational slots or empty informational fillers are empty concretizations, but not all of them are. For example, both an informational slot and an empty informational filler might be concretized by a sequence of bytes in a computer system, and an empty informational filler might be concretized by a pen stroke in a box. Also, the scenario of John indicating no middle name is especially relevant as it illustrates the three kinds of information emptiness: in that scenario, 1) the slot for the middle name is "empty" insofar as it is a slot, 2) the filler indicating that no middle name is provided is an empty filler, and finally 3) both this slot and its filler are concretized by the same empty pattern (which is thus an empty concretization).

As we saw, it is important to accept an ontology such that when an informational slot is processed in the way it is supposed to be, it is always filled – be it by an "empty" informational filler. Indeed, such a representation enables the satisfaction of an important mereological axiom of slot-company. Thus, our former theory in terms of mandatory slots that need to be filled for the parent slot to be filled and optional slots that can remain unfilled needs to be adapted. In the revised theory, all slots of a filled slot must be filled, and mandatory slots must be filled by non-empty informational fillers whereas optional slots can be filled by empty informational fillers. However, a slot can remain inadequately filled (as analyzed by [21]), a particular case of which would be for the slot to remain unfilled. Overall, this work on empty information is an important step towards the creation of a full theory of mirrored slots in the context of slot mereology for informational entities, that would combine former works on the mereological structure of fillers [29] and on mandatory and optional slots [5].

7. Acknowledgments

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