What is a Diagram?

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Abstract. We investigate the nature and typical features of the diversity of diagrams. Our paper is conducted in a philosophical perspective: it explores how to answer a question of the type "What is X?". It is an exercise in the methodology of philosophy through the example of the notion of diagram.

We start by the study of a typical diagram, a Venn diagram, and compare it with two apparently similar figures, that we call "pseudo-diagrams." We then go to the opposite direction, explaining what are obviously not diagrams.

We then present a cloud about the notion of diagram, commenting the cloud methodology. After that, we examine a series of things which are generally considered as diagrams: graphs, trees, charts, maps, tables, trying to show how they can be classified and categorized.

We furthermore go to the analysis of the notion of diagram using a theory of meaning, based on a diagram, the pyramid of meaning. We emphasize that though the notion of diagram cannot be reduced to the word "diagram", this word is invariant in many languages, trying to understand what this means.

We then discuss some limit cases such as pictograms or symbols. We end by proposing a characterization of the notion of diagram.

Keywords: Venn Diagram, graph, tree, chart, map, table, cloud, categorization, pyramid of meaning

1 A Typical Diagram and Two Pseudo-Diagrams

As an appetizer, here is a simple and famous example of diagram:

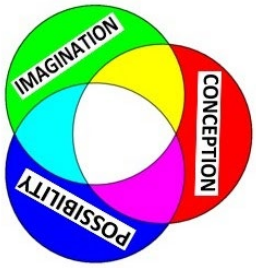

Fig. 1. A Venn diagram

We have here a two-dimensional visual image. To be less pleonastic, we could just say “a two-dimensional visual object” or even “a two-dimensional image”, “2DI” hereafter for short.

Let us compare this Venn diagram with two other 2DIs:

Fig. 2. A triangle

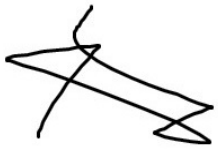

Fig. 3. An unidentified drawing

Both are “lines”. At first sight, one may say that the similarity between “things” in Fig.1 and Fig.2 is stronger than the similarity between those in Fig.1 and Fig.3. The Venn diagram of Fig.1 can be described as three circles, representing the relations between three notions. The graphic in Fig.2 represents a triangle. The line of Fig.3 does not represent anything. It is a thing in itself, a random drawing, a scribble.

But, from another perspective, Fig.3 is more similar to Fig.1, because of the value of the graphic aspect. In the case of Fig. 2, this aspect also exists, but if the idea, following the name of the figure, is to represent the mathematical object called “triangle”, the connection between the figure and the object is illusory. We have something that looks like an equilateral triangle, which is a particular case of triangle, and one may think that all triangles are equilateral. Moreover, it is not a “real” mathematical triangle at all since a mathematical line has no thickness. There is a great disparity between the graphic and what it is supposed to represent and the similarity is misleading.

In the case of the Venn diagram, this not a pure graphic like in Fig.3 but there is a better equilibrium between the graphism and what it represents than in Fig. 2. The reason why the three circles are of the same size is because a Venn diagram represents a general scheme for all possible relations between three notions. In a particular case one notion may be more important than another one and an intersection like the yellow space may not exist, but this is a design for the general setting. We have used the Venn diagram of Fig.1 in a paper examining the relations between imagination, conception and possibility [3], arguing that all the 7 spaces represented by the 7 colors exist. One of the reasons of the success of Venn diagrams is that it is a simple and nice tool to organize our thinking, and this can be considered as a typical feature of diagrams.

2 Images that are not Diagrams

When we want to characterize something, it is useful to work not only on a positive approach but also on a negative one. To have a look at what it is not. But not a classical “not”! The classical not is very abstract, general, and heterogeneous. This is the reason

why it is very difficult to picture it. For example, how to represent a non-cat? Below a tentative illustration of this entity [5]:

Fig. 4. 2DI for non-cat(s)

In the name of the figure, we have written “non-cat(s)”, because the idea of non-cat is described through a multiplicity of objects. A way to unify these objects would be to use the picture which is at the center of the figure below [5]:

Fig. 5. Three non-cats

On the left of this central figure, we have a typical example of a paraconsistent non-cat, something that can be considered as a cat and a non-cat. On the right, we have a typical example of a paracomplete non-cat, something that is not a cat, not in an absurd way like the number 7, but leaving space for it. Paraconsistent and paracomplete negations can be understood through the following two diagrams [5]:

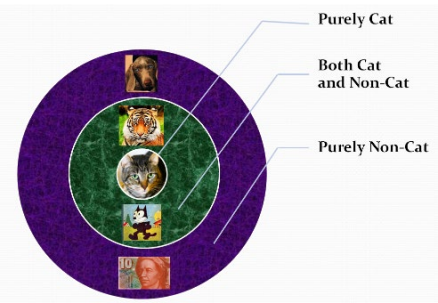

Fig. 6. Paraconsistent negation

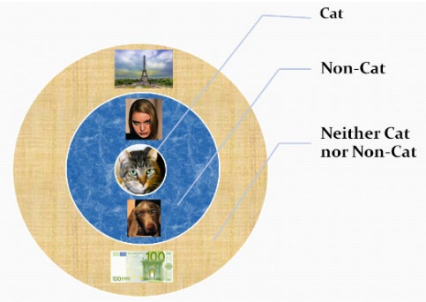

Fig. 7. Paracomplete negation

Back to our central dish, we can say that an omelet is classically not a diagram, but this is not so interesting in order to understand what a diagram is. In the previous section, we have put diagrams within the family of two-dimensional images. This first step was positive. And then we have presented two pseudo-diagrams, going in the direction of the tiger of Fig.5.

We can now have a second negative step in the line of the picture which is on right of the classical non-cat. A girl is an animal, a mammal, but obviously not a cat. What are non-diagrams in this paracomplete sense? Things which are 2DIs but obviously not diagrams. There are tow typical examples: photos and paintings.

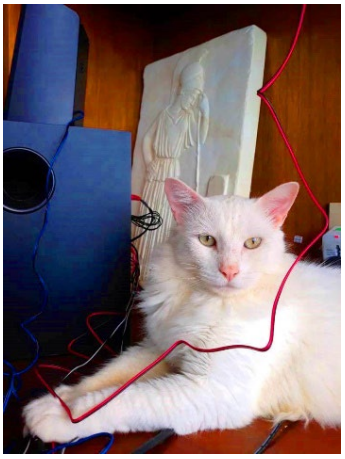

Fig. 8. A photo

Fig. 9. A painting

A photo is a 2DI which is a direct representation of reality, a painting is a 2DI which can represent something or not. In both cases, the basic reason why they are not diagrams is because there are not graphics (made of lines).

But then what about the following?

Fig. 10. Graphic of a man

In this case the reason is that, though it is a graphic representing something and there is a strong connection between the graphic and what it represents, it is not explaining anything, by contrast to the following famous graphic due to Leonard da Vinci.

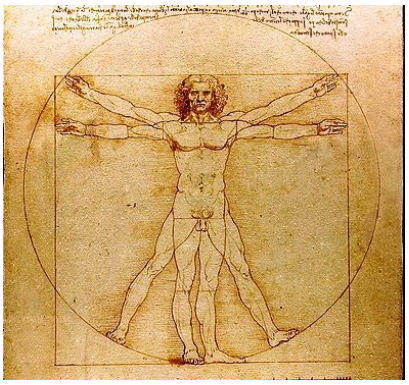

Fig. 11. "Vitruvian Man" by Leonard da Vinci

This drawing explains the ideal body proportions of human body, according to the Roman architect and engineer Vitruvius.

3 Organization of the Universe of Diagrams

There are plenty of diagrams. The universe of diagrams is very big. But is it numerous only in quantity, or also in quality? Are there many *types* of diagrams?

Let us first start with the following word cloud:

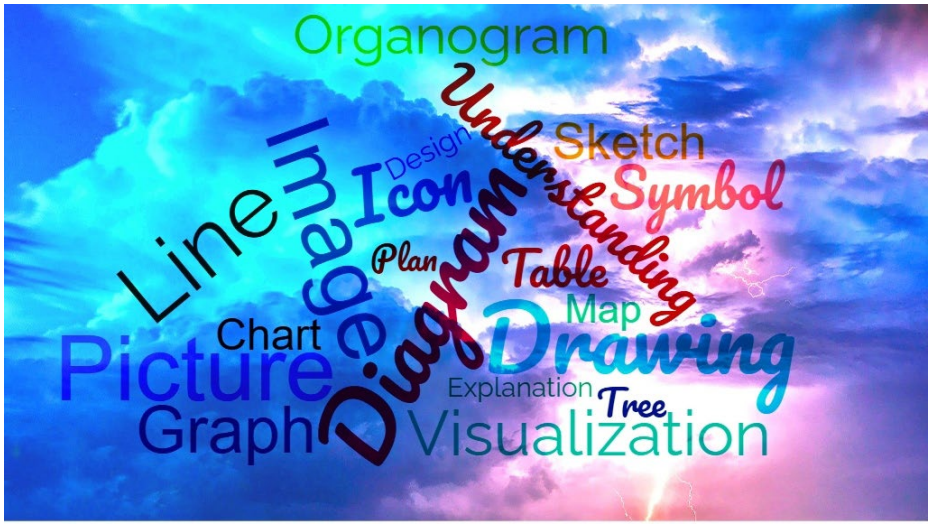

Fig.12. Diagram Word Cloud

The origin of word clouds has been traced back to [20], but they started to become very popular with computer programs and internet (see [30]). With a program you can easily build a cloud (as we did in Fig.12 above).

How does it work? Let us explain that in five steps:

(1) You choose a *keyword* upon/around which you want to make a cloud.
(2) You choose a *list of words connected to it*.
(3) For each of this word you choose *a calligraphy, a color and a size.*
(4) You choose a *form* to display these words.
(5) You choose a *background image and/or color*.

Here is a funny example, where the keyword is "key":

Fig. 13. Key Word Cloud

In the case of this word cloud, step four is the form of a key. This a common choice when there is an obvious form connected to the meaning of the keyword. In the case of "diagram" there is not such an obvious form, like a key for "key" or a heart for "love", the map of Paris for "Paris", but in some sense any design will do, let us explain why.

Based on the structure of a word cloud, which can be understood based on these five steps, let us examine if a word cloud is a diagram. It is a 2DI, so it is not to be excluded immediately. However, any set of words put in a page with some meaningful connections between them, like a poem, is not necessarily a diagram. What we have additionally in a cloud word is a *design*. "Design" is a key word for the understanding of a diagram. But if the design aspect of a 2DI can be seen as a necessary condition, it is not a sufficient one to turn a 2DI into a diagram. There is more in a diagram: it *explains* something, if possible, in a *beautiful* and *intelligent* way.

A cloud word can be nice, but it not always very intelligent, for three reasons: it is limited to words, the form is quite chaotic or artificial, the connection between the words is not very sophisticated. Let us explain that through the very example of a word cloud for diagram.

There are no precise rules for choosing the words surrounding a keyword in a cloud. The idea is that their meanings is related to the meaning of the keyword, but relation is a very wide concept. What is predominant is synonymity, in an extended way, as in the structure set up by WordNet [33] with its notion of *synset* based on conceptual relationships, which include *hyponyms*, *hypernyms*, *sister terms*, *derivationally related form*s. WordNet was launched by Princeton University in 1985. Similar projects were developed later on, such as ConceptNet [11].

This is not any kind of associations. This excludes in particular two things: enumeration of particular cases and opposites/antonyms. We will not enter here in details about the question of opposites. Let us just point out that in some cases it is quite meaningful for the understanding of some notions: love/hate, day/night, good/evil, and that the theory of oppositions using diagrams as basic tools, based on polygons (squares, hexagons, decagons, etc.) and polyhedra (cubes, dodecahedra, etc.) [12] has a wide range of applications for the understanding of fundamental notions (cf. [6], [7]). In the case of diagrams, there is not a strong opposite forming an inseparable pair and it is also not clear if other oppositions such as contrariety and subcontrariety can be useful.

Regarding enumeration, it is not very interesting to make a word cloud about "philosophers" putting a set of names of great philosophers or a word cloud for "natural number" putting 0, 1, 2, 3, 4, 5, … Excluding enumeration is a good thing connected with the famous mud example of Plato's Theaetetus. Socrates/Plato have been famous by putting ahead the question "What is?", and favorizing comprehension over extension. But at the end they did not provide a universal clue to answer such a question. We can answer a question "What is mud?" by "Earth mixed with water" or "What is an even number?" by "A number that can be divided by two". But, in many cases, there are no such simple answers and anyway it is good to have a general look at all the variety of things that may fall under the umbrella of a given concept, even if the objective is not to make a enumerative list of all of them.

The fact that the keyword of a cloud is singular points out a comprehensive dimension, as well as the fact that it does not include a list of particular cases. A word cloud is a middle term between extension and comprehension. To go for a deeper understanding, we need classification or categorization, in the present case, of diagrams. What are the different types of diagrams? We need to put order and structure. How to proceed?

To go to this direction, one methodology is to select a list of few *typical examples* of diagrams, with an exhaustive perspective: we want a good panoply. The expression "typical examples" points out that we are in the direction of types rather than a chaotic numerous enumeration. Since we are dealing with diagrams, we are lucky to be able to easily use some pictures to display a typical panoply of diagrams.

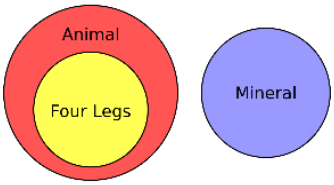

Fig. 14. Euler

Fig. 15. Tree

A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

Fig. 16. Table

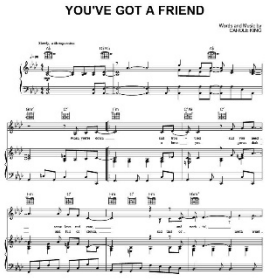

Fig. 17. Musical score

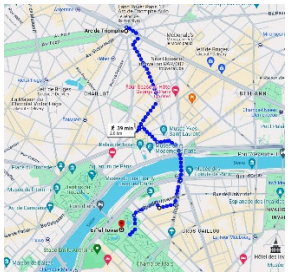

Fig. 18. Map

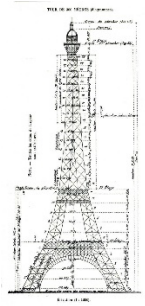

Fig. 19. Architecture

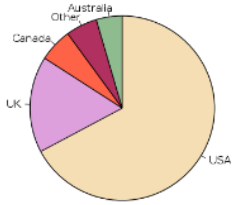

Fig. 20. Pie chart

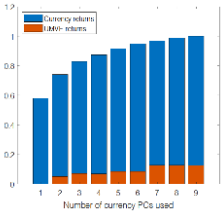

Fig. 21. Bar Chart

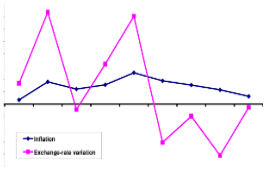

Fig. 22. Line chart

The next step is to try to group around these typical diagrams, all what it makes sense to call a diagram, not all that is or has been called a diagram. It is a way to examine what we could admit or not in the universe of diagrams. If necessary, we can add a new category obtained by this typification or suppress one if two are similar or one appears to be a subcategory of another one. The idea of categorization it to have a small number of exhaustive and (mainly) exclusive groups, the different *categories*, and to find good names for them. Categorization itself can be represented by a Euler diagram or a Pie chart and subcategories using a tree diagram. This is what we can roughly say about the categorization/classification methodology (for more details about that see [24]).

Let us see now how to apply this methodology to the notion of diagram itself. The diagram corresponding to Fig.14 (Euler) can be called a *potato diagram.* We can put in this same category Venn diagrams, although it is important to point out the distinction between assertive and descriptive diagrams and the fact that Venn diagrams are not a particular case of Euler diagrams (see [15], [21], [29]) . Fig.15 is a tree, a particular case of *graph*. We can put in this category any kind of graphs (in the mathematical sense, i.e. with nodes and arrows). This includes: flowcharts, commutative diagrams, astrological maps, organograms, and more. In Fig.16 we have a standard *table* with lines and columns. This concept is extended in different ways in particular when using the adjectives "tabular" and "tabulated".

The first line (Figs. 14, 15, 16) represents three categories of diagrams. These categories can be mixed, for example when representing a function in mathematics one generally combines potatoes with graphs. There is no real need to introduce a new category for this combination.

It is interesting to note the independence of a shape of a diagram and its use or meaning. On the one hand, diagrams of the same shape can explain quite different things, in different ways, on the other hand, diagrams of quite different shapes can be used for a similar purpose

Regarding the first point: a tree can be used to depict the organogram of a company or to perform reasoning, using the tree method. Regarding the second: to prove the validity of the law of excluded middle, one may use a truth table, a semantic tree or a Peirce graph/potato. Another example is illustrated by Figs. 17 and 18. One may say that both a music score and a directional map guide us in a journey based on quite different shapes.

An architecture plan can also be put in the same functional category: it guides us to build an edifice. From this point of view the three diagrams of the second line (Figs. 17, 18, 19) can be put in the same functional category, that we can call "guiding". But they have not the same shapes. The three categories of line 1 are by shapes. From the point of view of shape, a music score is tabular in a loose way and the directional map of figure 18 can be seen as a graph.

Regarding Fig.19 it does not correspond to any of the three categories. Shall we build a category upon it and if yes, what would be its name? It can be seen as a graphical (not a graph!) description of how something works (or should), not reducing it to a specific form than can be applied to other situations. "Vitruvian Man" by Leonard da Vinci (Fig.11) can be placed in this same category. Let us have a look at other diagrams having the same characteristic:

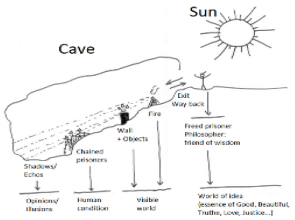

Fig. 23. Plato's cave

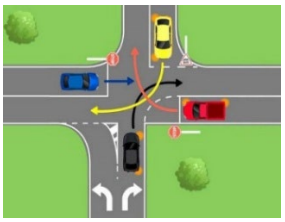

Fig. 24. Crossing an intersection

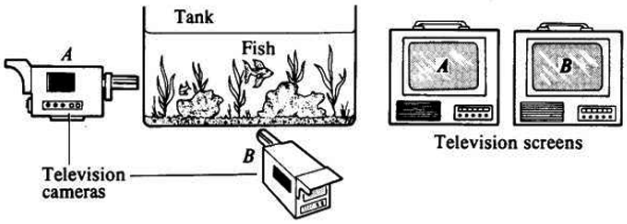

Fig. 25. David Bohm's metaphor for inseparability [8]

Which name can we give to this category? Let us just call it *Map*, because these diagrams are mapping an objective reality. Moreover, a canonical example of diagram of this category are geographical maps. So, by now, we have 4 categories: Potato, Graph, Table, Map.

Let us go to the third line. Figs. 20, 21 and 22 are all called "charts", but what is a chart? It is interesting to note that this English word does not have a proper translation in French. Reverso [26] proposes three alternative French translations for this English word: "graphique" (graphic), "tableau" (table), "diagramme" (diagram).

The word "chart" appears in "flowchart", which is a graph, and an organogram, also a graph, is alternatively called an "organizational chart". So, there is a connection between graphs an charts. A line chart can indeed be seen as a graph, but what about pie charts and bar charts? They can be put in the same functional category (as well as line charts): "graphical representation for data visualization", data meaning some quantities/ numbers. But if we call this functional quantitative data category "chart", it is confusing to call an organogram an "organizational chart". If we consider chart in the restricted sense of graphical representation of quantities, among these charts there are many shapes inclusive maps (cf. Worldmapper [32]).

Funny enough, the word "chart" is from French *charte* "card, map," from Late Latin *charta* "paper, card, map"… The meaning "sheet on which information is presented in a methodical or tabulated form" is from 1840; specifically in the music score sense from 1957 [14]. We see that there is a connection with one more category, the table category. Chart is indeed a kind of catch-all category for diagrams, so it not surprising that it can be translated in French just as "diagram". The conclusion is that chart is not a category of diagrams and at the end we stay with four categories.

4 The Pyramid of Diagram

Up to now, we frequently have used the expression "The notion of diagram". Let us explain why. We have developed a theory of the notion that is a kind of extension of the Saussurian theory of the signified and the signifier [27], a pair that he qualifies as a sign, which is not the usual meaning of the word "sign", the common sense corresponding rather to what Saussure calls signifier.

Our theory has the form of a pyramid [4]. Its basis is a triangle with corners: idea (thought), thing (reality), word (language). The notion is at the top of the pyramid that encompasses all three aspects by supervision:

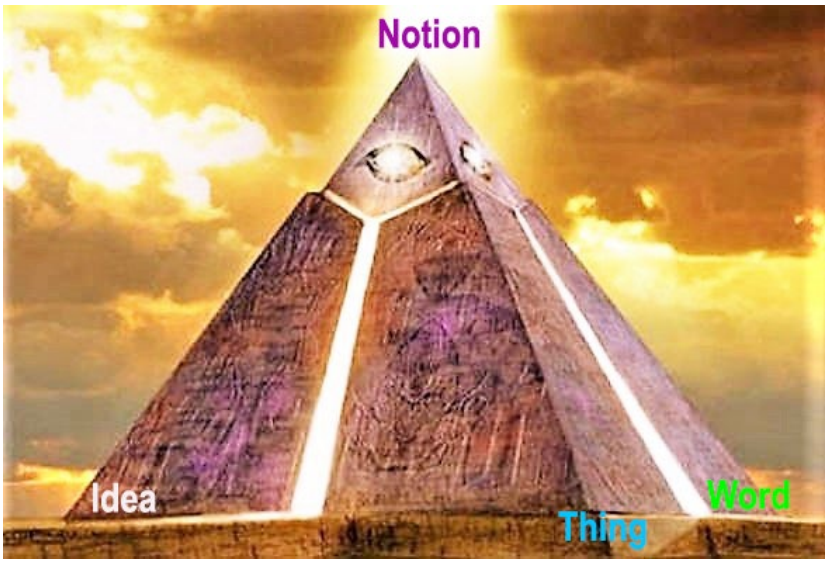

Fig. 26. Pyramid of Meaning

First, let us ask, is this pyramid a diagram? One may prefer something like that:

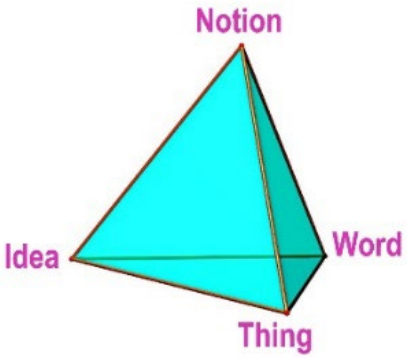

Fig. 27. Tetrahedron of Meaning

A tetrahedron is a mathematical object, an elementary simplex. A Venn diagram is also based on a geometrical object. There is another similarity with a Venn diagram: the basis of the tetrahedron is an equilateral triangle. Depending on the notion, one corner of the basis can predominate, for example, in the case of the sun, reality predominates. This is what comes first, the idea of the sun is much attached to this reality and the word

"Sun" is secondary, in particular it varies quite a lot from one language to another: in the Inca culture, where the sun is key, the name for it is "Inti". But the idea is to have a diagram that includes equally all the cases, like with a Venn Diagram.

Regarding the difference between Fig.26 and Fig.27, we can ask: up to which point a decoration turns a diagram in a non-diagram? Two things are important: to really have a diagram behind the 2DI, the decoration should not be more important than the diagram and should be in harmony with it. This is the case of our pyramid: the diagrammatic aspect of the 2DI can be extracted, as shown by Fig.27 and the pyramid corresponds to the shape of the diagram, a tetrahedron is in fact also called "a triangular pyramid". The image of the pyramid is certainly quite strong, due to the symbolic meaning of a pyramid. But it makes sense considering that the pyramid is related to the great Egyptian culture, one of the most impressive in the history of humanity, and is connected to knowledge and understanding. Furthermore, the eye at the top of the pyramid, corresponding to the notion, symbolizes the fact that we must see all the aspects of a notion. At the end, we can say that Fig.26 is more illuminating than Fig.27 both being diagrammatic.

There is another interesting point: we have here a three-dimensional object, but it is represented in a two-dimensional image. For this reason, we can say that the diagram is itself two dimensional.

Let us now present a pyramid of meaning for the notion of diagram:

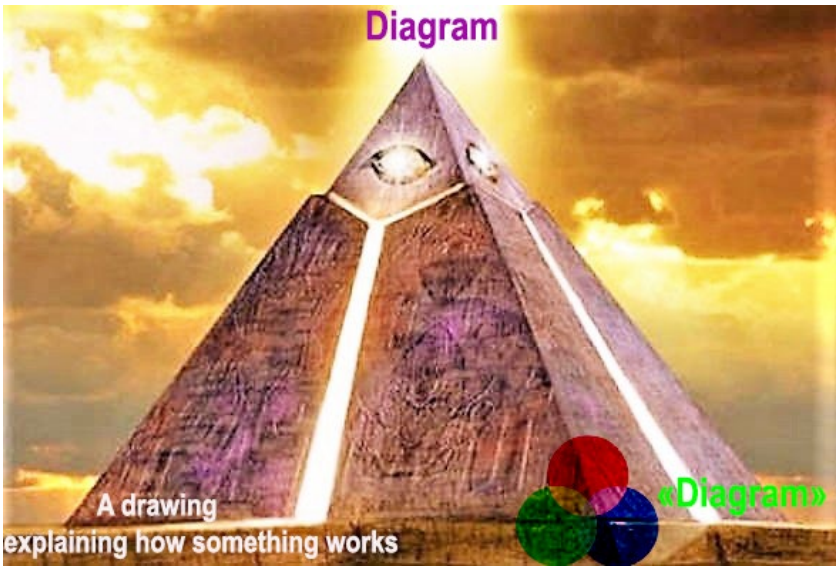

Fig. 28. Pyramid of Meaning for Diagram

The idea (thought) corner is a concise formulation of the usual definition of a diagram. It is a mix and simplification of the characterizations of *Wordnet* [33]: "a drawing intended to explain how something works, a drawing showing the relation between the parts" and *Wikidata* [31]: "plan, drawing, sketch or outline to show how something

works or the relationships between the parts of a whole". The second part "the relationships between the parts of a whole" is important if we think or organograms or trees in general, but in some sense, it is included in the first part.

For the thing (reality) corner, we have chosen a Venn diagram because it is a well-known diagram and, though it is specific, it is general, being applicable to many situations, and also because it is in harmony with the idea corner.

For the word, we have used "Diagram", because our paper is written in English, but the word is rather invariant under the multiplicity of languages, as shown by the following picture:

Fig. 29. Wikidata – Diagram in 49 languages [31]

This situation contrasts with notions like sun or love where the word varies quite a lot. Can we say that due to this invariance the word corner is dominating in the notion of diagram? Not necessarily, in particular because the etymological sense of "diagram" (*through drawing* [14]) only weakly corresponds to the idea, by contrast with another invariant word like "Philosophy". The case of "Diagram" is more like "Pajama" or "Taxi", its universality is perhaps related to its morphology/sonority.

What we can say is that in the case of the notion of diagram, there is a good equilibrium between the three corners of the triangle.

5 Characterization of the Notion of Diagram

In this final part we will present a characterization of the notion of diagram, considered in a general perspective (compare to [13], [16], [19], [28]). Such a characterization is certainly (a bit) normative. If we put under the same umbrella all which is, or has been, called "diagram", this will not give us an understanding of what a diagram is. This is in fact true for any notion.

Scott Christianson in the book *100 Diagrams that Changed the World* [10] considers cave paintings as diagrams. This is certainly an exaggeration. But this is a recreational book and it must be considered as such. A more meaningful book is *The Power of Images in Early Modern Science* [18] by Lefèvre *et al.*. Obviously, many of these images are not diagrams and the authors do not pretend they are.

The question is not "Are they (cave paintings or other 2DIs) *really* diagrams"? but "Does it make sense to *qualify* them as diagrams?" To reply to this question, we need a characterization of diagrams.

There are indeed two kinds of things we want here to exclude from the universe of diagrams: pictograms and symbols.

Here are two examples of pictograms:

Fig. 30. Horse in Chinese

Fig. 31. Coffee place

A pictogram is a picture of something. It is more or less explicit. In the case of the sinogram for horse, we do not immediately recognize a horse. The evolution of sinograms has turned them less and less explicit, but the Chinese language did not make the jump to alphabetic language where the structure of meaning is radically different from ideogrammatic languages. We are talking about jump, because alphabetical letters were at first pictograms [23], the most famous case being the first letter of the alphabet, originally a pictogram for the head of a bull. The cup is a pictogram used to indicate a place where you can drink coffee or something similar.

The reason why we can consider that these drawings are not diagrams is that they depict without explaining, they are just informative. They are symbols in the etymological sense, signs where there is a connection between the sign and its meaning, in the present case a visual connection, what Peirce calls "icons" (see [1], [9], [25]).

Symbolism has another dimension. Let us have a look at the two following pictures:

Fig. 32. Justice

Fig. 33. Equality

Both are pictograms, but their meaning does not reduce to the thing they are picturing. The balance is use to represent justice and the two parallel lines, equality. They *symbolize* these notions. What does this mean? The pictured object is a typical object through which a general concept is expressed metaphorically [2].

Can we say that a symbol in this strong double sense is a diagram? Not really, because the symbol can give a generic idea but does not explain/depict how things work. You cannot practice justice just by weighting in the material sense of a balance. The same with equality: when we say two things are equal it is in general not in the sense of two parallel lines, and this symbolization does not give a clue of how to "identify" things. This works only in very specific cases where you put two things side by side, for example two people to check if they are of the same height.

Peirce made the following comments about diagrams: "A diagram should be as iconic as possible; that is, it should represent relationships by means of visible relations analogous to them. (CP 4.433) Icons are especially requisite for reasoning. A diagram is mainly an icon, and an icon of intelligible relations (CP 4.531)." [25] Iconicity is fundamental but we need something else, as here stated by Peirce, although he is insisting on iconicity

We propose the following characterization of the notion of diagram: *A diagram is a key to understanding and operating based on an iconic two-dimensional visual graphical explanation of a structure or a phenomenon.*

It is important to add to "understanding", "operating", because when we use diagrams for performing a proof [22], going somewhere, or playing a piece of music, we are not just understanding. It is also important to put side by side "structure" and "phenomenon", because diagrams catch both the concrete and the abstract, the fix and the moving.

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