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The fractal geometry of Luhmann's sociological theory or debugging systems theory

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ABSTRACT

Social theory faces new challenges as society changes. The question is not only if social theory can keep up with –and account for– social transformations, but also if it can avail of social changes (in this case, the current dominance of digital media) in order to reinvent itself. The most attracting features of modern digital resources, such as Big Data, lies on their tools of analysis. But it just might be that the most promising contribution to social theory resides in the epistemological foundations backing these developments and the conceptual tools they can offer to rephrase epistemological issues. In this sense, the function debuggers play with regard to their target programs could shed new light not only on the process of knowledge formation, but also on the process of theory-improvement/ updating. The present contribution intends to show how theory-debugging might work, by taking the sociology of Niklas Luhmann as a target program to be debugged by fractal geometry with the goal of delivering an enhanced version of system theory. It concludes by arguing for the plausibility of describing communication as a natural fractal susceptible of being modelled by some kind of fractal set, and for how communication media are responsible for the fractal structure of communication along sociocultural evolution.

1. Introduction

Once algorithms were an abstract and weird idea developed by philosophers of mathematics and few people knew about them and what the word actually meant; nowadays it is hard to think of someone who have not heard the word at least once, not to mention the fact that, unlike in the past, algorithms are doing things for us all the time. A data revolution has shaken the world changing in unexpected ways how we interact with other human beings and with this new ecology of artificial forms of intelligence (an interface some call Global Brain (Heylighen and Lenartowicz, 2017)), how we do business, how we teach and how we learn, how we read the news, how we search for information, in short, everything we know, the things we do (Mayer-Schonberger and Cukier, 2013) and even the pace of life (Wajcman, 2008). And science, of course, is not the exception.

Doing science in an information society brings many questions to the fore. To what extent are Big Data, Data Science, AI, Deep Learning, among others, changing the way science constructs knowledge, (i.e. to put forward and test hypothesis, construct theories and deal with the problem of the nature of knowledge and the foundation of knowledge-claiming statements, create concepts and objects of knowledge, and so on)? (Berthon et al., 2000; Boyd and Crawford, 2012; Kitchin, 2014; Lash, 2002) Can algorithms make the scientific method obsolete? (Anderson, 2008) Can algorithms substitute humans in the process of abduction by suggesting the researcher an array of emergent patterns out of his data base? Are the new statistical tools of Data Science reinforcing and radicalizing empiricism? Or the mere availability of bigger in volume, real-time, diverse, exhaustive, fine-grained, relational and flexible data sets (Kitchin, 2014, p. 1–2) help little to support certain philosophy of science, but simply provide science with more powerful analytical tools to further research instead? And what is the place of the social sciences in this scenario? Are we at the brink of a digital transformation of social sciences and humanities? (Berry, 2011; Cohen, 2008; Lazer et al., 2009) What shall be the role of social theory in this context? How could social theory avail of the advantages that these new tools have to offer?

Certainly, developments in Big Data by no means would lead to the end of theory (Kitchin, 2014, p. 5) for decades of theoretic-philosophical debate and experimental research have enabled its very emergence and, furthermore, asking the right questions to data requires theoretically-informed guesses. In this sense, the most important contribution computer science could make to social theory consists in the heuristic philosophy backing AI, Deep Learning and/or Neural Networks (Pearl, 1984). In other words, a promising path towards thinking of a digital transformation of social theory would imply taking an epistemological turn by rethinking how problems are posed and how to

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think of problem-solving.

Social scientists are usually unconfident about problem-solving style of thinking, considering the ability to ask questions more important than that of giving answers. The reason is that they tend to think of answers as a termination, as putting an end to a debate. Questions are fundamental, for sure, because the problems questions raise prompts scientific discoveries. But solving a problem actually means to give it a tractable form, to be able to handle it without excessive or inefficient effort, and to rely on its results in order to galvanize further research. As a consequence of this misunderstanding on problem-solving, social scientists tend to devote too much effort in intractable or truly tractable but ill-defined problems.

In addition, computer science could teach social sciences how to (re) think of theory-design. If theories are observed as programs (i.e. chains of binary operators capable to codify and bring about information) executing certain kind of tasks, such as providing answers to the questions posed or giving explanations to problems introduced, it is possible to evaluate their performance by examining their structure, code and even running some sort of 'theory-debugger' in order to check for errors (namely, inner contradictions, insufficiencies, logical incoherence, and so on) (Roth, 2017).

This thread can be meaningfully followed by recurring to the description of the science system provided by the sociology of Niklas Luhmann. As Roth (2017) argued, the sociology of Luhmann can indeed be read as a digital theoretical design –at least as long as it is observed under the concepts and formulae of the *Laws of Form* of G. Spencer Brown (1972). Luhmann (1989, pp. 76-83) describes science as a functionally differentiated and operationally closed system reproducing communication autopoietically by means of a binary code (true/ not true). The operation of the code engenders oscillatory and memory functions resulting in temporality (a time dimension of its own); and at the same time, the crossing of one side of the Form[1] to the other (true ↔ not true) makes room for imaginary values to emerge (also called in the parlance of von Foerster, *Eigenvalues*), having as a consequence that the operational closure of the system achieves cognitive openness (Luhmann, 1997, 1989, 1992, pp. 88–114). The code symbolizes the unity of the difference in the system and simultaneously represents a brief statement of its inherent paradox. In order to start up the autopoiesis of scientific communication the system needs to unfold its paradox by devising natural or artificial paradox-unfolding strategies (Luhmann, 1990, 1999). Programs are useful to this purpose because they create asymmetries and/or operationalize the code. Scientific programs consist of theories and methods: theories represent openness by externalizing scientific results, while methods operate inwards applying the code and standing for closure. Scientific programs also produce self-structured resonance determining the manner how science gains information about its social environment (Luhmann, 1989, p.79). The former state of affairs responds to a general feature of the Form of communication, namely, double closure (von Foerster, 2003) –which is represented by the distinction of operation and observation. For certain, the evolution of scientific communication has depended on the differentiation and generalization of cognitive expectations, a process that has led science to excel at the production of distinctions separating observations from operations. In other words, this means that science is particularly keen on asking for the grounds, foundations, or sources for verification of every statement wielding knowledge-claims –in fact, Luhmann describes science as the second-order observation of knowledge-claims (Luhmann, 2008, 1992).

There are two kinds of strategies in order to account for the foundation of a knowledge claim, namely, appealing to external reference or to self-reference. Allo-referential strategies ground knowledge in things other than itself e.g. the subject, the Being, faculties of the soul or the mind, human consciousness, observation of regularities in the real (empirical) world, and so on. Self-referential strategies ground knowledge on itself. Philosophy has discovered some kind of self-reference by supposing that the locus of human knowledge is consciousness (e.g. the philosophical tradition of knowledge of the self) (Taylor, 1992), but this is not a proper self-referential foundation of social knowledge. Conversely, an example of the latter is given by the same Luhmann. The German sociologist considers that a theory of society ought to reflect on its very theoretical status, because social theory only becomes possible as a reflexive theory (Esposito, 1996; Luhmann 1975, p. 193; 2002).

This statement has far-reaching consequences. It means that the theoretic design of Luhmann is, from an 'epistemological' point of view, neither empiricist nor transcendental or phenomenological.[2] It is a self-referential theory design –usually called constructivist. Therefore, its validity and foundations lie on the very same circularity of the theory. There is no object to refer to; there is no synthetic a priori guaranteeing the foundations of all human knowledge; there is no subject or consciousness on whose experiences all knowledge depends. Available are only the ephemeral operations of an operationally closed autopoietic system, whereby closure brings about cognitive opening (being equally valid for living organisms, humans, AI algorithms, and social systems as well). Foundation is then self-foundation, and every inquiry into the ground of a theory is enabled by the recursiveness of communication and the power of dissolution and recombination of the elements of the system of science.

However, dealing with self-referential conceptual schemes (or descriptions) can easily derive in trivial tautology if a mechanism is not devised in order to produce determination or de-tautologize the respective theory (Luhmann, 1986). Back in the third decade of the 20th century, when the field of logics and mathematics was revolutionized by the findings of K. Gödel debunking the Hilbert-program, the Austrian-American logician stumbled on the same problem and concluded that systems of that kind were undecidable (i.e. there were no rule for deciding what is true and what is false). Unfortunately, Gödel –among many others following the tradition of analytic and/or language philosophy– conflated problems of truth with problems of reference (Luhmann 2002, pp.64–65; 1999, p. 15). The fact is that the problem of truth –especially if understood as word-object or thought-Being correspondence– and the fallacies regarding knowledge hidden behind the widely disseminated metaphor of the mirror of nature (Rorty, 1979) have not only impeded finding an adequate solution to the question of knowledge, but also, even more strikingly, they have not allowed a clear-cut statement of the problem to be solved. In this context, Luhmann (1986, 1975, p. 196) argued that completeness shall be substituted by self-reference, and that, since contradictions in self-referential theoretical statements cannot be solved by resorting to the object, determination can only be achieved by establishing *mutual limitation relationships* between self-referential theories, namely, making that theory A constrains what theory B can meaningfully state and vice versa.

The concept of mutual limitation relationships (limitation is a concept borrowed by Luhmann from economics) is often difficult to understand. Limitation consist in the restraints resulting from selection. It plays the role of *contingency formula* of the success medium for truth. As examples of limitation count: the logic of genres, typologies, laws or statistical regularities, the principle of falsifiability, and functional equivalences (Luhmann, 2008, pp. 157–169). The latter description could be cleared, furthered and complemented by the notion of 'theory-debugger'.

In the field of informatics a debugger is a program designed with the

[1] In the following, *Form* as in the parlance of systems theory and formal calculus will be written with capital letter, while the geometrical conception of *form* will be written with lower case.

[2] The philosophy of science of Luhmann might fit Peirce epistemology if the place of consciousness is displaced by a communication circuitry consisting of abduction, induction and deduction.

goal of detecting errors or bugs in other programs, usually called target programs. Debuggers simulate the target program, fully or partially, and test it for logical or programming errors. In order to perform their duty they must operate as 'translators' or 'interpreters' between different codes or programming languages. This feature –often taken for granted in informatics– is crucial, because it implies that a theory debugger must be able to deliver equivalences between theoretical languages which are commonly incommensurable. Debuggers, in the parlance of systems theory, would not only stress restrictions derived from selection, but would also point at plausibilities, connections, equivalences, and convergences. Besides, debuggers not only translate and interpret programming languages, they simulate the program and intervene in it by correcting errors. Therefore, a debugger is a mean for theoretical recursiveness, helping theories to correct themselves in the process of scientific inquiry. In short, a debugger shall be able to enhance the target theory by underlining its links with other theoretical productions and to create new, up-to-date, versions of it.

Roth (2017) was the first to advance theory-debugging by employing the NOR design of Spencer Brown for double contingency tables, in order to run a test routine for error-checking and updating the differentiation theory of Luhmann (with which Roth achieves a major shift of emphasis in the system-theoretic design from re-description to re-calculation, strengthening thereby the super-theory program that Luhmann initially conceived). The German sociologist considered that crosstabs played a major role in science as a Form of limitation or limitationality (Luhmann, 2008), for that reason substituting cross-tabs by matrices will fulfill the same function. Hence, debugging is a complement or functional equivalent to limitation/mutual limitation.

Of course, there is nothing about debugging that science does not already do. Precisely, that is why the notion of debugging might be useful to deliver new insights and more self-awareness about how scientific knowledge corrects itself (or how science dissolves and recombines its elements) in the process of knowledge production. Thus, this is how the author of this paper proposes to interpret how a digital transformation of social theory would look like: treating theories as programs that can be debugged in order to actualize new versions of it –a description with the immediate consequence of leaving aside analogic procedures such as hermeneutics (certainly, not of every kind), where the intention of the author, as a human and conscious agent, remains crucial.

The purpose of this paper is then twofold: first, to show an example of theory debugging in the case of Luhmannian systems theory (target program); second, to employ fractal geometry as a debugger able to enhance or update the social theory of N. Luhmann.

2. The sociology of Niklas Luhmann

The theory of society of Niklas Luhmann pivots around the concept of communication, then for the German sociologist society is nothing but communication. Communication is described as a triple selection of information, utterance, and understanding/misunderstanding. Understanding represents the unity of the difference, because comprehension is the standpoint from which the difference between information and utterance can be observed. Since an observer cannot do without distinctions and distinctions are equivalent to cognitive operations, understanding equals to distinguishing.

As long as observers are able to make distinctions in the medium of meaning and to observe distinctions already made, the difference between information and utterance will regenerate once and again keeping communication going. The three selections are always simultaneously involved in every communicative operation; it is impractical to treat them separately, running otherwise the risk of confusion (e.g. selecting an information already implies being able to distinguish between information and some kind of communicative behavior).

On the other hand, communication is a self-referential and recursive Form. Every definition or statement (selection) presupposes a distinction at the other side contouring not only the conditions of possibility for the selection made, but also what becomes possible next (redundancy). There arises a surplus of possibilities demanding again selection and re-actualizing redundancy. Communication is therefore recursive, because it iteratively applies the same operator (distinction) to the outcome of previous operations. Communication is also self-referential, then the property of re-entry of the Form into the Form not only enables communication to communicate but also to communicate about communication (Luhmann 1995, pp. 137–175; 2002b).

As stated above, Luhmann's theory of society claims to be reflexive, not only because it reflects on its own theoretical status, but also because it comprehends itself as a social description among many others in the social system. According to the German sociologist, a reflexive theory of society could only be brought about by establishing mutual limitation relationships between three self-referential theories, more specifically: systems theory, communication theory, and evolution theory. Let us take a closer look at how mutual limitation works in the sociology of Luhmann.

Evolution theory enables a more complex restatement of systems theory for the reason that it highlights the fact that the principle of differentiation is only but a contingent choice in the context of sociocultural evolution. The same is true for systemic references: they only attain full development in our modern functionally differentiated society. Evolution theory, in turn, requires systems theory and communication theory in order to explain how evolutionary mechanisms (variation, selection, and stabilization) differentiate and distribute their functions. Language is described as a dissemination medium structured by a yes/no binary code assuming the function of engendering variety. As a consequence of language potential for negation, causing that not every communicative event is accepted, there arises the need to guarantee the transmission of selection performances. This is the function accomplished by symbolic generalized communication media (or success media); communicative success thereby becomes the hallmark of evolutionary selection. On the other hand, the contingency spawned by the chances of rejection and acceptance of communication furthers the differentiation of more mechanisms for variation and selection, that is, dissemination media such as writing and the printing press (Luhmann, 1990b). And finally, when systems evolve, a sufficiently complex selection is no longer able to achieve stability and guarantee the reproduction of evolutionary solutions. As a result, a new re-stabilizing mechanism emerges: system formation (Luhmann 1975, pp. 197–200; 1975b, 2005, 2012, 2013). These three theories constraining each other constitute therefore the founding pillars of the sociology of Luhmann.

Dirk Baecker can be seen as a precursor of the further digitalization of the system theory of Luhmann, for Baecker (2007, p. 60) reconceptualizes communication as a Form in the strict terms of the formal calculus of Spencer Brown. Communication is thereby conceived as indication ¬ distinction. From this basic Form and the degrees of freedom it brings about, several other Forms of communication can be described (at least, as referring to communication in the medium of meaning-processing) such as functions, systems, persons, media, networks, and evolution (Baecker, 2007, pp. 146–253). In contrast to Luhmann, who considered indication ¬ distinction as an application of a more general problem of surplus-and-selection, Baecker argues that the calculus of Spencer Brown is the most general and abstract standpoint from which communication and observation can be conceptualized (Baecker, 2007, p. 65).

As a matter of fact, the reconstruction of the theory of communication by Baecker is of great interest. Nevertheless, it offers the chance to stress that there are currently several versions of the sociology of Luhmann in the scientific market. Although the author of this essay intends to stay as close as possible to the original source code, it is inevitable to make complexity reductions from a non-unitary literary corpus and to take a stance in sight of controversial issues –after all, 'Luhmann' is not but a metonym of a collection of texts. Indeed, if reading is nothing but actualizing a background of distinctions and values that will produce difference and meaning against the target text/theory/program, it is inevitable to the author of this text to make his own copy –and/or to run his own debugger.[3]

Accordingly, two issues will be put forward before going on. The first one concerns the second constituting selection of communication, namely, utterance. This parlance is currently employed by the English translators of the work of Luhmann in order to account for the German word *Mitteilung*. However, *Mitteilung* literally means communication, notice, announcement or notification, significations that are not at all grasped by the concept of utterance. On the other hand, utterance has clear linguistic connotations –namely, employing vocal cords to emit a sound– which impede to take into account functional equivalents to articulating phonemes. Although translators (and Luhmann himself) might have had good reasons for their decision, the author would rather to employ the syntagm *'communicative behavior'*, or even better *'selection of a communication medium'*, as the fittest terms –after all, maybe the original concept of *Mitteilung* is not concise enough either. As Watzlawick et al. (1967) have argued, all behavior is communicative, for there is a whole spectrum of contexts where communication plays a role that cannot be reduced to linguistic articulations. From this standpoint it will be possible to understand the role of communication media in sociocultural evolution and it would also be possible to account for communicative structures that do not depend on human vocalizations (and which, in some cases, are independent of the human mind –e.g. bots or intelligent assistants) to set communication forth (Esposito, 2017).

The second one regards the concept of meaning. Again, the author disagrees with the current translation of the German word *Sinn*. Although Luhmann himself translated *Sinn* as meaning, the semantic load of the concept makes it much harder to distinguish between linguistically articulated horizons of action and experience and those horizons that shape expectations and actions in absence of any linguistic performance. As a matter of fact, semiotic systems create their own meaning surpluses, but orienting one's behavior to that of others often operate at a pre-linguistic level. Losing sight of this difference often leads to a strictly semiotic –although interesting– reading of Luhmann (Lenartowicz, 2017). The difference also makes sense when it becomes pertinent to distinguish between social semantics and the information processing that functional systems carry out (i.e. semantics and social structure). In the same guise, from an information-theoretic point of view, being able to distinguish between information and meaning represents an edge whilst trying to bridge humanities and natural sciences within a transdisciplinary framework. Therefore, instead of meaning the author would rather to talk about '*sense-making'* in order to cover linguistic and non-linguistic information processing as well. As the reader could notice, this is not merely a matter of translation, on the contrary, it is about theoretical decisions with far-reaching influence in the kind of questions we can ask to the theory and the kind of answers it can deliver.

3. Fractal geometry

Euclidean geometry has ruled over two thousand years determining our notions of nature and space. Its influence has been so powerful that it practically became an ideology that instead of describing nature as it is, ended up imposing a rational model on nature. The revolutionary character of fractal geometry consist in providing more accurate descriptions of nature by accounting for the monstrous, deviated, fragmented, and irregular. Benoit Mandelbrot (1983, p. 4), in fact, coined the word fractal from the Latin *fractus*, meaning broken, irregular, fragmented. With fractal geometry, mathematicians aim again at describing nature, instead of ruling over nature.

The intuition behind fractal geometry suggests that there exist types of form beyond the comprehension of topology, which repeat again and again onto themselves; in other words, one finds in nature self-similar patterns that remain invariant when scaling up (Mandelbrot, 1983, pp. 18–19). This intuition challenges not only topology –which, for instance, within the frames of its current conceptual schemes, cannot account for the difference between coastlines–, but also the notion of dimension conceived strictly as a number of coordinates. Beyond Euclidean dimensions, where all dimensions coincide, there are dimensionally discordant sets in nature. Therefore, argues Mandelbrot (1983, pp. 14-17), the notions of dimension and form need to be expanded in order to grasp the most common features of natural objects. Dimensions shall be conceived in terms of the scaling properties of a shape (Feldman, 2012, p. 163); while the nontopological features of form shall be called fractal forms (Mandelbrot, 1983, p. 17) and studied from this standpoint.

A fractal set can then be defined as "*…a geometrical object whose self-similarity dimension is greater than its topological dimension.*" (Feldman, 2012, p. 169; Mandelbrot, 1983, p.15). This kind of surplus is what defines the D dimension or Hausdorff dimension, namely, a sort of in-between space that does not correspond to any of the traditional dimensions and equals to a non-integer.

A crucial distinction is that between natural fractals and fractal sets. The former consist in natural patterns that can be usefully represented by fractal sets; it is important not to lose sight of the fact that natural fractals are only self-similar up to a certain scale or range of magnification (Hutchinson, 2000, p. 128). The latter refers to a geometrical abstraction that serves as a model or first approximation to structures and shapes found in nature. In any case, in order to properly define a natural phenomenon as fractal, it has to be described by a specific fractal set (Mandelbrot, 1983, p. 128). Furthermore, fractal phenomena are closely intertwined with scaling laws; for that reason, the researcher has to consider that "*…to each scaling law, there exists exactly one compact set (fractal) satisfying that law*" (Hutchinson, 2000, p. 137).

Fractal geometry constitutes undoubtedly a transdisciplinary paradigm, since fractal geometries are found not only in natural sciences, but also in social sciences, such as economics, finance systems, and arts. In fact, in a recent study, G. West (2017) argues that cities and organizations follow the same scaling principles as living beings do; hence, cities and organizations own fractal dimensions too. However, telling what fractal geometry has to offer to enhance our understanding of society, culture, politics, semantics, and so on is not that obvious. In fact, at first sight, one might be tempted to answer: "it has nothing to do with it!" But what if by examining the convergences of two transdisciplinary approaches, such as the sociology of Luhmann and the fractal geometry of Mandelbrot, one could convincingly argue that fractal-like structures are a universal property of complex systems? This is an exciting research field to explore. The challenge is to show how to think of scaling and scaling properties with regard to social systems.

Certainly, there are some incompatibilities between Luhmann and fractal geometry. First, fractal geometry speaks the language of set theory, but the sociology of Luhmann derives from an intellectual current that developed under the criticism of set theory of Georg Cantor and the mathematical logic of Russell & Whitehead, due to their inability to deal with paradoxes (Zermelo-Fraenkel set theory did not solve the problem either; they just found a way to avoid paradoxes). Accordingly, if set theory cannot account for paradoxes, fractal geometry, being phrased in that language, would be leaving aside the most prominent trait of the system theory of Luhmann –or how then can fractal geometry account for paradoxes? On the other hand, fractal sets are, in fact, recursive, but, can they behave reflexively? (i.e. is there any case in which fractal patterns observe themselves as fractals and use

[3] These statements fit nicely within the classic thesis of Gadamerian hermeneutics, although framed in self-referential and strictly communicative terms (i.e. without the need to refer to conscious processes –which is not to say that these are not co-participant in communication by means of structural coupling in the Form of perception and sense-making).

this "fractality" to orient a process of further fractal-making?). Second, although both theories rest on certain logical-mathematical philosophy, they assume antagonistic positions: fractal geometry follows an intuitionistic tradition, while Luhmann sympathizes with formal logic –especially, as it is well-known, the Spencer-Brownian logic. Third, as stated above, social theories –including that of Luhmann– scarcely rely on statistical methods, such as probability distributions, in order to deliver generalizations, but that is exactly what fractal geometry does. Therefore, either a quantitative interpretation of the sociology of Luhmann or a qualitative reading of fractal geometry shall be advanced, or maybe, it would possible to find a compromise between both extremes.

Nevertheless, there is no reason to be pessimistic about the aforementioned difficulties. On the one hand, the intuitionistic background of fractal geometry has an advantage: it allows a loose and creative interpretation of fractals, instead of demanding rigorous proofs. Therefore, it is possible to extrapolate fractal theory in order to think of social systems; the only requirement will be finding significant isomorphisms between both theories.

On the other hand, there are also certain coincidences that deserve to be highlighted. Mandelbrot (1983, p. 197) claimed that every strange attractor can be considered as a fractal if D, instead of being read as a measure of irregularity, is taken as the piling of smooth curves upon each other (i.e. another way of interpreting fragmentation). This is very interesting because since 1995 Luhmann became acquainted with the concept of attractors and dynamical systems by the hand of the literature related to cognition, memory, and perception. Soon, he began to apply the notion to crucial aspects of his theory, such as evolution (concretely, he speaks of "evolutionary attractors"), functions, binary coding, self-descriptions, medium and form, and redundancy. For instance, Luhmann (2000, p. 139) conceives functions as evolutionary attractors that, under adequate circumstances, influence the orientation of the evolutionary process. He describes binary codes as cyclic attractors that, by interrupting their own circularity, allow the introduction of new conditionings that enable the system to increase complexity (Luhmann 2013, p. 91; 2013b, p. 75). He thinks of a stable attractor resulting from a dynamic of describing descriptions and observing observations which furthers more descriptions and observations, and he asks himself about the operative conditions that would make it plausible to last (Luhmann, 2013, p. 314). Therefore, one might wonder: is not there any strange attractor in the social systems described by Luhmann? Given the contexts in which Luhmann used the concept, it is not unlikely.

The aforementioned convergence on attractors unveils dynamical systems theory as a suitable translation language for debugging. Not only dynamical systems play an important role in fractal geometry and vice versa, but also the sociology of Luhmann can be rephrased in the language of dynamical systems.

Dynamical systems theory concerns with forecasting the long-term behavior of all points of a given space *S*. There are different kinds of dynamical systems. Those of most interest are non-linear higher-dimensional systems and dissipative dynamical systems, for the reason that they exhibit complex, at-the-edge-of-chaos, and chaotic behaviors. Non-linear higher-dimensional systems and dissipative dynamical systems, as a result of their long-term unpredictable behavior, usually harbor strange attractors. Strange attractors are chaotic from a dynamical point of view whilst from a geometrical perspective they tend to be fractal (Hirsch et al., 2004, pp. 155–157; Peitgen et al., 2004, pp. 627–630).

In order for a fractal/dynamical system description of the theory of Luhmann to be plausible enough, it has to deal thoroughly with a defining trait of that theory, and there is hardly a better candidate than communication.

4. Communication and fractals

There are two alternative descriptions of communication in social autopoietic systems theory. The original ternary description made by Luhmann and the binary Spencer-Brownian re-description put forward by Baecker. Taking the *Laws of Form* as a departure point, although plausible, would become cumbersome for the reason that it will require a new translation, namely, from Spencer-Brownian formal calculus to dynamical systems. Conversely, the ternary description of communication looks more promising.

The communication triad of Luhmann can easily be paralleled to a three-dimensional dynamical system. Information would stand for a measure of uncertainty –as Shannon (1964) conceived of it– whereby a definite number of bits codifies the magnitude of possibilities out of which a selection can be made. Nevertheless, there cannot be any information outside the context of some medium, such as the human body, language, writing, printing press, social media, and so on. In this regard, the concept of channel capacity can give insights into the possibilities that different media offer to codify information (e.g. Gary Urton (Mann, 2003) calculated that cuneiform writing is able to codify among 1000 and 1500 bits of information while Andean khipus might have codified up to 1536 bits). On the other hand, the selection of a communication medium is contingent and the decision itself usually becomes significant. As a consequence, there is on the one side the actualization of a Form or selection within a determined medium and its inherent uncertainty, and on the other side there is the difference between the performances of different media –this is how the difference between objective and social dimensions of sense-making (i.e. a difference between what and who or how) is brought about by social evolution. Finally, understanding, as an observation, is a happening, a selection. But what selects understanding? Understanding chooses an attribution of meaning and/or makes sense of a situation; understanding fixes Form-Medium relationships (whereby the fixation becomes a Form in itself) leaving a mark or trace from which further Form-Medium configurations emerge. Information, selection of media/behavior and understanding are interdependent variables, not only because they can hardly be defined separately, but also because the values of one selection are in dependence of the values adopted by the others.

It is not hard to image information, media/behavior and understanding as communication coordinates in a Euclidean space. Furthermore, if communication is understood not as an action or segmented in units, but as a process, it will be possible in principle to trace communicative trajectories. Think, for instance, about conversations; they are bursty processes with peaks and valleys, moments of intensity almost to the point of cacophony and moments of boredom. Not every conversation happens the same way; novelty and surprise has to be produced all the time to keep the interest. Think also of reading books. Some catch the reader's interest up to the point they cannot do anything but reading until the book is finished. Some of them are boring and left aside. Some of them are difficult and demand too much time and effort. Books become best-sellers, and they do so because they feed up conversations and readers make recommendations to other readers. In any case, there are many examples of communication bursts along and among different media (Karsai et al., 2018).

The idea that the author intends to advance is that communicative trajectories might also exhibit the same kind of behavior as the trajectories of dissipative and/or non-linear higher-dimensional dynamical systems. It is not far-fetched to see attractors emerging in communication all the time –e.g. an issue in everyone's lips, a common place, a saying, and so on. In the same guise, basins of attraction can described as cultural background providing themes, concepts, common places, values, rhetorics, discourses and the like.

Accordingly, if communicative trajectories exhibit attractive dynamical behaviors, they might also give rise to strange attractors and fractals. But let us take a closer look to the notion of strange attractors before assuming communication processes show this kind of dynamics. There is no agreement among mathematicians upon what defines a strange attractor, but some of the most reputed hint at five properties that a set A with fundamental neighborhood *U* must satisfy (Ruelle, 1989, pp. 24–27):

1) Attractivity: for every open set $V \supset A$ there is $f^t U \subset V$ for every large enough t.
2) Invariance: $f^t A = A$
3) Irreducibility: a point $x' \in A$ such that for each $x \in A$ there is a positive t such that $f^t x'$ is arbitrary close to x.
4) Sensitive dependence on initial conditions.
5) Stability under small random perturbations.

Thinking of isomorphic relations between social autopoietic systems and strange attractors, several things to consider come to the fore. First, time plays a significant role in dynamical systems theory and this is an important feature when comparing trajectories with the autopoietic reproduction of communication. Therefore, dynamical systems have the potential to represent and/or simulate sociocultural evolution. Second, descriptions of dynamical systems are produced in the language of set theory –and, as stated above, that represents in principle a difficulty. However, sets can be considered Forms of allo-descriptions while the concept of system can be reserved for cases when dynamical behavior itself distinguishes between their own operations and those of the environment and is able to deliver self-descriptions of this state of affairs. Third, set theory can also be a useful tool to describe the evolutionary process of the out-differentiation of the social system by pointing at the dynamics behind function, code, semantics, system differentiation, media differentiation, structural and operative couplings. Fourth, sensitive dependence on initial conditions might explain the differences in complexity, structure and distribution of functions between social systems. Fifth, the properties of invariance and stability under small random perturbations can be considered as an equivalent to self-organization, in fact, strange attractors in themselves can be considered as self-organized communicative structures. The thing is that operations need reference points from which to depart and against which to produce effects, and that is precisely what a relatively invariant dynamical structure does. Sixth, social evolution prompts indeed dynamical regions (or sets) where several attractors (strange or not) emerge. The test of irreducibility could equate to the identification of a code giving rise to a functional system and/or crowning the evolution of determined success medium. Irreducibility and differentiation –that is a conceptual pair in need of further research.

If communication processes harbor strange attractors, communication ought to be fractal, and if communication is fractal there arises some questions to be answered: supposing communication is a natural fractal, does communication reproduce under some kind of scale law? If so, which would be the scaling properties of communication? Is there a D dimension of communication?

4.1. Scaling laws of communication?

There is hardly an answer for the question above within the frames of the oeuvre of Luhmann (at least, at first sight). Notwithstanding, the mathematical theory of communication of Shannon & Weaver, as inspiring as it was for Luhmann himself, can render some hints.

Provided that information has been defined as a manifold of choices available to be selected for communication, as a measure of uncertainty, Shannon (1964, pp. 32-33; Weaver, 1964, pp. 9-10) considered that information could be measured by the logarithm of the number of options at disposition of the information source. To the American mathematician, electrical engineer and cryptographer, logarithms to the base 2 seemed more reasonable than logarithms to the base 10 to do the job –although the last option was not rejected at all. Accordingly, being logarithms the inverse operation of exponentiation, scaling is implicitly involved –and logarithms, of course, are also commonly used in fractal geometry.

Shannon thought of logarithms to the base 2 because he was interested in a practical measure unit. Shannon (1964, p. 32) proceeded under the following assumptions: The linear variations that those logarithms produced were appropriate to deal with engineering parameters such as time, number of relays, and so on; linearity was also suggested by intuition as a fit measure, and calculus thereof was mathematically more viable. However, West (2017, pp. 21-30) has convincingly argued that thinking intuitively of scales in terms of linearity usually leads to error. In fact, scaling properties of complex systems tend to be non-linear (sublinear or superlinear). Therefore, one can thoughtfully ask, beyond concerns about measurement, if communication really behaves linearly or, contrarily, nonlinearly.

Anyhow, communication may be considered to scale as a function of information, namely, if the magnitude of information grows, so does the scale of communication. In this sense, the scaling of communication is equivalent to gaining complexity and expanding *sense-making* horizons as well. There might be some evidence indicating a nonlinear scaling behavior of communication. The psychic environment of social systems could set a limit to the growth of information in society for the reason that communication depends on the structural coupling of human attention and attention is limited by the neurobiological settings of our brains. However, are new communication technologies –presumably enabling algorithms to communicate (Esposito, 2017)– capable of breaking this limit?

4.2. Scaling properties of communication

In geometry, there are four topological dimensions: 0 (point), 1 (length), 2 (area), and 3 (volume). A shape is said to be self-similar if fitting into itself a number of times. For instance, let us have a three-dimensional shape, such as a cube, and magnify it by 5. How many cubes will fit into the bigger cube? This problem is solved thanks to the following equation:

$$\text{Number of small copies} = (\text{magnification factor})^{D}$$

where D stands for dimension. So, we get

$$5^3 = 125$$

We have then found the self-similarity dimension of the respective cube. So far, so good. Now, if the same equation is applied to a non-standard shape (e.g. snowflake patterns drawn on a plane) of unknown dimension, the result will be a non-integer. Seen the other way round, there are certain types of shapes where the actual dimension D exceeds its topological dimension (D_T). Those shapes are fractal because its D dimension is found in-between any of the known dimensions (i.e. if D_T equals 1, the D dimension will be D + 1, and so on). In fractal geometry, topological dimensions (length, area, and volume) are also understood as scaling properties or dimensions of fractals (Hutchinson, 2000, p. 140).

But how can a nonstandard shape be self-similar? Fractal geometry certainly performed some kind of interpretive turn in key geometrical concepts such as dimension, topology, and also self-similarity. According to Mandelbrot (1983, pp. 37-38), a nonstandard shape is self-similar as long as "*the whole may be split up into N parts, obtainable from it by a similarity of ratio r (followed by displacement or by symmetry)*". Besides, it is important to recall that strange attractors are also fractal because the iterative piling of curves at the basin of attraction can also be considered as a measure of (or an alternative to) irregularity (Mandelbrot, 1983, p. 197). Therefore, any shape fulfilling these requirements shall be treated as fractal.

Let us now turn to social systems. How is it possible to think about dimensions of communication?

A first approach to this question was advanced by Heinz von Foerster (2003) in an essay in honor to Niklas Luhmann. The Austrian cybernetician identified three dimensions of communication, namely, (recursive) functions (1), operative closure (2), and double closure (3). Functions are operationally open, linear; they are trivial machines since their past states do not influence their future states. When functions feedback they become operationally closed, non-linear; they are non-trivial machines because their behavior is influenced by their own operational history becoming unpredictable as a result. Double closure occurs by means of the integration of two operationally closed circuits; the integration of functions have functors as an outcome; functors give rise to a functional equivalent of hierarchy, namely, heterarchy; heterarchical organization allows operators to become operands and vice versa, causing functors to acquire freedom of action. As a corollary, von Foerster (2003, p. 322) describes communication as the Eigen behavior of a recursive operationally double closed system.

The answer of von Foerster to the question of the recursiveness of communication is outstanding for many reasons, however, the equivalence of dimensionality and scaling is a remarkable feature of the latter description. Function, operative closure, and double closure hint at some scaling law regarding to degrees of self-organization or complexity-degrees (provided that what is at stake is not the sheer number of elements, but the functions (relationships) that engender new element-relationship configurations).

Functions refer to ephemeral processes (just like communication trajectories being attracted and/or repelled), while operational closure and double closure are precise descriptions of operations differentiating between system and environment. That is, after a definite number of iterations there arises Eigen behaviors, Eigen values, attractors, and strange attractors; a system emerges, thereby, when a dynamic behavior is capable to observe its own operations and to trace a distinction between self-reference and allo-reference (what kind of strange attractors are these? –that is a question in need of further research).

Hence, von Foerster dimensions/ scaling of communication account primarily for system differentiation. Nonetheless, there is a problem with the concept of communication of von Foerster. As discussed above, the reproduction of social communication always take place within some media, as a consequence, there cannot be any satisfactory theory of communication without explaining the role media play.

A way out could consist in finding the place of media within the dimensionality-scheme drawn by von Foerster. In this regard, is there any relationship between communication media and the scaling up of communication? Are media the D dimension of communication?

Let us have a closer look at the idea that communication scales up by increasing information. By conceptualizing communication in terms of autopoietic reproduction, Luhmann has put the emphasis on the process character of communication. Ergo, instead of considering communication as a discrete unit, one should think of it as set of continuous trajectories. Observing communication processes as trajectories implies bringing to the forefront both, namely, a temporal dimension characterized by the hiatus between the ephemeral and duration, and the selectivity leading to some options whilst discarding the rest. As stated above, selectivity in systems processing sense-making opens up a surplus of reference and surplus-possibilities that demand selectivity in turn. The more extensive this surplus is, the more complex the system and the more information it brings about.

Now, is there a pattern (meaning a self-similar pattern!) characterizing every communication process no matter how long it lasts or the selections it performs? In fact there is. Communication processes begin by being very informative and end when they cease to be informative. This is equivalent to the thesis of the burstiness of communication studied by Karsai et al. (2018). Communication bursts because information is entropic; moreover, the fact that communication can reproduce among different media (e-mails, cell phones, human interactions, etc.) not only shows similar patterns of burstiness, but also evidences that providing a manifold of information sources stirs up communication once and again. This is how complexity-gain triggers in social systems, namely, by diversifying its information sources or communication media (i.e. increasing information, gaining in complexity, and employing sense-making in order to reduce and simultaneously conserve complexity).

But, is it possible that communication media are the D dimension of communication?

4.3. The D dimension of communication

There are two questions left to explore: What remains invariant across scales? And which is the D dimension of communication –that is, the extra dimension beyond topology? The answer to both questions is deeply intertwined and it regards communication media.

In order to understand media and the role they play in the growth of information and the multiplication of information sources, it is important to dissociate the concept from usual connotations such as mediation and transmission. Communication media do not intermediate between two sides of the communication process, whether consciousness and society or among two persons/consciousnesses or more. Transmission, on the other hand, consist in the performance of communication technologies that avail of the physical properties of determined physical media (e.g. radio waves, electronic circuits, quantum physics, etc.) in order to codify and transmit signals. But signals do not communicate by themselves; signal-decoding becomes informative when instantiated within a communication process –be it as a motivation or complement. Transmission is thereby a technology that has made room for new highly technical media to emerge. But neither transmission nor mediation explain or describe what communication media actually do.

The distinction medium/Form developed by Luhmann (2000, pp. 102-132; 2012, pp. 113-120) describes, to put it briefly, a relationship between loose coupled and tightly coupled elements. The medium is the unity of the difference between medium and Form. Therefore, a medium presupposes the gathering of a plurality of elements sharing similar properties; these elements are able to couple and decouple, combine and recombine in different forms just like Lego pieces; media are flexible, because they can produce outputs suited for different occasions –or as Luhmann (1987, p. 101) put it: "*Media differ from other materialities in that they allow a very high degree of dissolution*". But elements cannot combine and recombine at will, there are certain transformation rules governing every medium. In a sense, communication media are ruled by algorithms. For instance, the structure of a language establishes which phonemes make sense when uttered in sequence; the writing and grammatical conventions of a language determine what combinations of vowels and consonants represent real words; even the physiology of the human body limits the set of gestures and postures that might make up the body language of a culture.

However, although elements and rules for combination and recombination are limited, the combinatory potential of media is exponential –keep in mind the examples of artificial languages given by von Foerster (2003) and Hofstadter (1999). In this sense, in every medium there is always a difference between the possibilities enabling the current operation, the possibilities opened up by the very selection being made, and the wider unactualized possibilities that the medium offers. In addition, the existence of multiple communication media adds new horizons expanding the realm of communication possibilities. In short, media produce a huge surplus of possibilities of communication (seen the other way around, these possibilities represent uncertainty, hence, information).

Luhmann (2012, pp. 18-27) defined as sense-making precisely this surplus reference obtained from actuality, but since sense-making is a universal medium –namely, a medium of media– the *differentia specifica* of media operating within sense-making remains an open question. As a consequence, the suggestion is to call *mediality* the emergent property of communication media. To put it briefly, mediality refers to the information-generative potential of a medium –a potential that can be measured in bits. Seen from another perspective, a medium is an information source and its own information source as well.

If we think of media in terms of their dynamics, namely, how do they interact among each other (and how do they behave with regard to social systems, i.e. interaction, organization, and functional systems), it becomes necessary to think of a concept to describe such state of affairs. The author will coin the novel concept of *medial coupling* in order to account for these dynamics.

The idea of medial couplings refers to the observation that communication media actually couple among each other like a matryoshka doll (e.g. the embeddedness of writing in printing press and contemporary electronic media such as Twitter, Facebook, and the like; the re-contextualization of oral communication, usually ruling over interaction systems, in those very same electronic media; or the conversion possibilities of power into money and vice versa). There are five features of medial couplings:

- The condition of possibility of medial couplings rest on Forms spawned within certain medium becoming the medium of another sort of Forms. Coupling hints at the interactive and interdependent character of media evolution. Communication media have the ability to reinforce each other's differentiation, as in a positive feedback loop, becoming dependent of each other's output (e.g. think of the effect of the printing press in the transformation of power, especially, reaching structural reflexivity: power controlling power) –but as history also reveals, there are also negative feedback loops among media (i.e. dynamics where political change is impeded, such as the use and effects of propaganda in totalitarian regimes).
- The amount of media in the social system boosts information by means of the mere availability of more options to perform communication. However, every medium in its own internal constitution of medium and Form, creates a range of possibilities and a code of their own to which other media are blind. Therefore, the concept of coupling is used here in an analogous sense to the structural couplings of functional systems (i.e. as fulfilling the function of converting analogic [data?] into digital [information?]). When coupling, information is not just added up; new media mean new sources of information.
- Medial couplings increase the complexity of the relationship between meaning and information. This means that the same type of communicative structure acquires novelty and different meanings/ senses by being actualized within different media. For instance, declaring one's love is not the same if said, written, e-mailed, texted, tweeted or posted on one's Facebook wall. The very choice of a medium tells something. Let us say you write a love letter; you just do not write down the words “I love you”. The choice made implies the use of certain linguistic conventions (e.g. poetic language, the use of rhetorical tropes, or, plainly: fulfilling the writing conventions of what is currently considered romantic); those conventions are nested within determined semantic fields ruled by certain metaphors, images, or *distinctions directrices* that condition the way words are used and understood; and, on the other hand, that very choice makes available certain kinds of attribution schemes to make sense of it (e.g. writing a love letter is romantic/writing a love letter is outdated and ridiculous, and so on), or even the contingency of the selection is employed to infer something about the personality of the lover.
- Medial couplings beget resonance and dissonance simultaneously (i.e. agreement and disagreements are potentiated in the same proportion) making the problem of the acceptance of communication more pressing. This process leads to –and reinforces– the full structural development of success media.
- Medial couplings have the effect of increasing the complexity of time and of temporalizing complexity (Luhmann, 1993). Sequential temporality is already implied in autopoiesis, but when communication thickens its volume and multiplies its information sources, the result is a complex set of time-dimensions where past, present and future intertwine and acceleration crops up as a by-product. The fact is that the existence of a plurality of communication media which can couple in several ways makes it possible to reconstruct possibilities that were left behind by choices made in the past, and this reconstruction succeeds not only by observing the contingency of the choice made, but also by creating redundancy and structure that engender analogous choices. This causes the past to pluralize as a function of present operations and their expectations projected in the future; recycling options by means of fusing time-horizons, satisfy the steady demand for novelty of complex systems, but when there is exceeding supply, social acceleration raises forcing expectations to collide and face disappointment –unleashing far-ranging consequences in the social system (comp. Luhmann, 1976, 1997; Rosa and Scheuerman, 2009; Koselleck, 1989, 2000).

Consequently, if there is something invariant across communication scales it has to be some kind of surplus-ratio where communication possibilities surpass what can be achieved in a single communicative process. However, uncertainty and certainty, determination and indeterminacy, redundancy and variety must keep some kind of proportional relationship in order for communication to reproduce autopoietically. If there is too much uncertainty communication is impossible; if there is no uncertainty at all, communication becomes unnecessary. If there is not enough redundancy communication is unsuccessful; if there is too much redundancy communication is superfluous. It is the creation and maintenance of this sense-making-surplus (= meaning + information-surplus) what puts social systems at the edge of chaos; it is because of the asymmetries and bifurcations produced by that surplus that sociocultural evolution is set forth (comp. Leydesdorff and Ivanova, 2014). And media and their couplings, as shown above, play a major part in this drama.

But how is it that communication media can exceed the topological dimensions of communication and become fractal? How is it possible?

In order to proof that mediality/ medial couplings represent the fractal dimension of communication, communication media ought to portray some parallelisms with strange attractors –many of which are considered fractal. Therefore, the behavior of communication media as a function of time should exhibit the following properties: attractivity, invariance, irreducibility, sensitiveness to initial conditions, and stability under small random perturbations (Ruelle, 1989, pp. 24–27).

The first thing to cause uneasiness might be considering media as sets. Nevertheless, the difference medium/Form can be paralleled to the relationship between boundary set and open set. The idea of an open set tunes in with the dynamics implied by the difference between medium and Form, since open sets represent open intervals in the real line; elements in the open set can acquire any value within the frames of the boundary set, just as Forms couple and decouple within the domain of the respective medium. Another way to describe mediality by means of set theory notions, consist in considering medium/ Form as the inclusive relationship of a universal set U consisting of finite elements, possessing an open subset V. Of course, set theory do not mirror exactly the properties of media, nonetheless if iterated long enough, media would fulfill the condition $f^t\, U \subset V$, namely, *attractivity* (Ruelle, 1989, p. 24).

Communication media possess, as said above, a surplus-ratio that must be kept *invariant* across scales, otherwise communicative autopoiesis run the risk of ceasing –or, in less dramatic cases, complexity-gain stagnates. There is also another point of view from which to consider invariance. Although communication media evolve (i.e. vary, select/are selected, and stabilize), relative invariance must for certain be a defining property of their behavior. Success media achieve invariance by means of the development of a code –and before this achievement profiled and stabilized, they did it through the differentiation of a domain of the sense-making-dimensions where the mere selectivity motivated engaging in communication processes. Dissemination media, on the other hand, remain relatively invariant in the domain of the semiotic systems envisaged and/or in the (representation) technologies employed to depict them. Invariance is what makes communication trajectories to be attracted (or eventually repelled[4]) to certain forms of selectivity with the potential either to increase the probability of acceptance (success media) or to expand the reach of communication processes in space, time, and the degree of involvement of alter (dissemination media).

As said above, *irreducibility* could account for differentiation since what is looked for, in geometrical terms, is to exclude other possible attractors within the basin of attraction or the set explored. But irreducibility might also be the result of the dominant behavior of certain strange attractors/media, for instance, power and writing can be very dominant: political power tends to exclude or subsume other forms of social influence, while writing in the long run tends to override oral conventions of communication and social memory; on the other hand, couplings between media can produce the same effect: power and writing can work together so as to exclude other media either of success or of dissemination.

If communication media history is considered from a cross-cultural and non-teleological perspective, it will become clear how *sensitive to initial conditions* communication media are. Civilization theories usually consider writing the hallmark of civilization. Nonetheless, what is understood by writing is very narrow and ethnocentric (Harris, 2001). There are many other semiotic systems with quite different technologies of representation (e.g. think of the Inka khipu, the fine-line ceramics of the Moche culture, just to name a couple of unconventional examples). The point is that different environmental, cultural and technological conditions give rise to functionally equivalent but different forms of communication media in terms of their rules of transformation, complexity, mediality, and coupling networks. Even civilizations with alphabetic writing differ widely in their evolutionary trajectories.

Finally, communication media do remain *stable against small perturbations*. Variations, in order to trigger structural change, must be selected (and therefore, iterated) and stabilized –a point in no need of further clearance because it complies smoothly with the theory of evolution of Luhmann (2012, pp. 275-312).

These considerations authorize the conclusion that communication media are the fractal or D dimension of communication.

5. Concluding remarks

The present contribution has intended to suggest how the idea of debugging a software can be extrapolated to the critical process of evaluating a theory and contributing to its improvement. Commonly, the fate of a theory is bound to the author who developed it; critique is usually considered, by both the critics and the critique-observers, as an attack to its validity pretensions; and contributions face difficulties in integrating to the theory because they are scored in other's author record and tend to be treated separately when studied and taught. But if we think of theories as they are, not only someone's creation, but first and foremost as a set of enunciations and concepts logically concatenated and having to deal with problems of incompleteness, self-reference and paradox, it is possible to remove the constraints regarding the anthropocentric self-descriptions of theorizing. The keen reader will surely notice that the author has insisted about Luhmann once and again, but Luhmann, to say it again, is nothing but a metonym for a theoretical corps that happens to be developed in its most part by someone called Niklas Luhmann. But the most important is not what Luhmann, the human, had in his mind, but the potentials emanating from the texts he left to further systems theory (which, it shall be stressed, is a performance of communication media).

The second idea exposed along these lines was showing how a theory-debugger might work. For that case, Luhmannian systems theory was the target theory to be debugged (and, as a result, strengthened) by Mandelbrotian fractal geometry, whereby dynamical systems theory fulfilled the role of a programming language. It was found that communication may be treated as a natural fractal describable by some kind of fractal set, concisely, strange attractors. The questions raised here are essential to confirm or reject this idea, however, the answers shall be considered exploratory and provisory. Further, the tentative answers provided along the text aim at showing there are some interesting analogies or convergences between both theories (so as to establish a mutual limitation relationship that locks them in a self-referential loop), but, in order to give a more formal and sophisticated answer, further research is required. For instance, there is maniple of questions in need of future exploration:

- What is the relationship between irreducibility and differentiation –if any?
- Scales up communication non-linearly?
- What kind of strange attractor is an autopoietic system?
- How do strange attractors (media) behave in interaction with other strange attractors?
- Can this framework provide suitable tools for modeling and faithfully simulating social systems and sociocultural evolution?
- Mediality and medial couplings deserve further research regarding theoretical-debugging and modeling and simulation experiments
- Is there any case in which fractal patterns observe themselves as fractals and use this "fractality" to orient a process of further fractal-making?
- How could strange attractors account for paradox?

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[4] Let us think, for instance, of secrecy: the need to codify messages that only the recipient could decode, has been responsible for many technical advances in communication transmission and the development of semiotic systems –think of the history of computers, think about those languages and writing systems reserved for the sacred and/or the royalty. The paradoxical effect of secrecy is remarkable, for exclusivity became a means for massification. But there are other examples, such as the resistance to change in traditional contexts or even the varying patterns of social disregard/ acceptance that can also be considered as repelled communicative trajectories.

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