

# Reflections on mathematical figures and engineering approaches in anthropology

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## **Abstract**

This paper presents and discusses some examples of how mathematical figures and engineering approaches can be detected in anthropological theorizing and how a mathematical reading of certain anthropological theories is possible and sometimes fruitful. The paper proceeds in three steps: a comparison between experimental measuring and engineering “black boxing” as different ways of representing ethnographic reportage and anthropological theorizing; a discussion of feedback loops in anthropological theorizing; and a discussion of chaos theory and fractal geometry and some of their uses in anthropological writing. I finish by hinting at the fruitfulness of making allies across disciplinary boundaries given our anthropocenic predicaments and limitations in our cross disciplinary analogies.

**Key words:** mathematics and engineering, anthropological theory, chaos theory.

# Reflexões sobre figuras matemáticas e abordagens da engenharia na antropologia

## Resumo

Este artigo apresenta e discute alguns exemplos de como figuras matemáticas e abordagens de engenharia podem ser detectadas na teorização antropológica e como uma leitura matemática de certas abordagens antropológicas é possível e às vezes frutífera. O artigo desenvolve-se em três etapas: uma comparação entre a medição experimental e o método de “caixa preta” da engenharia como imagens diferentes da reportagem etnográfica e da teorização antropológica; uma discussão de feedback na teorização antropológica; e, finalmente, uma discussão da teoria do caos e geometria fractal e alguns de seus usos na escrita antropológica. Terminando sugerindo a fecundidade de fazer aliados através das fronteiras disciplinares, dados nossos apuros antropocêntricos, bem como algumas limitações em nossas analogias interdisciplinares.

**Palavras-chave:** matemáticas e engenharia, teoria antropológica, teoria do caos.

# Reflections on mathematical figures and engineering approaches in anthropology

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## Introduction

After several years of teaching anthropology it has become noticeable to me that social science students tend to have a considerable aversion to mathematics, a sentiment often born during earlier phases of their education. The common separation between the hard and soft sciences often leaves students of the latter with little interest and knowledge of the former and a general impression of mutual incompatibility. This paper is not a systematic review of any intellectual intersections between the hard sciences and anthropology, it simply addresses this “intellectual gap” by presenting and discussing some examples of how mathematical figures can be detected in anthropological theory and how a mathematical reading of certain anthropological approaches is possible and sometimes fruitful.

It should be clear from the outset that this article is not about ethno-mathematics, or about mathematical tools deployed in social science methodologies, like the use of statistics in sociological analysis or other quantitative methods used in fields like medical anthropology or human ecology. In terms of the relationship between mathematics and anthropology, following Lévi-Strauss’s consideration of the subject (1954; 1963: 283), I am much more attracted, for example, to the affinity between what Lévi-Strauss called “qualitative mathematics” (ibid.: 585) – referring to group theory and topology – and social anthropological research.

Any attempt to explore the relations between mathematics and anthropology risks being criticized from two positions: either the result is overly metaphorical and lacking in rigor from a mathematical standpoint; or it uses math as a mystification or as an artificial appearance of scientificity, from an anthropological vantage point. I have strived to maintain a satisfactory degree of rigor, drawing from my early training as an engineer, and I am certainly not trying to persuade anyone of the value of anthropology by appealing to its “hard” scientific credentials.

In this context, in this article I review some ways in which ideas resulting from my dual training as an engineer and anthropologist have come to frame each other in my writing and teaching. I shall proceed in three steps. First, I compare Malinowski’s methodological recommendations for conducting fieldwork with Lévi-Strauss’ methodological guidelines for building structural models. I affirm that the first is modeled on a representation of ethnographic reportage as experimental measuring, whilst the second is analogous to the engineering process of assuming a black box and discovering its transfer function (both are explained below). This comparison also contrasts the role of change in each procedure. The second section discusses the analytical use of feedback loops, and how they can be suited to ethnographic analysis of social life, given that feedback can capture the inherent recursiveness we find in social processes. My main anthropological examples draw on the work of Gregory Bateson among the Iatmul and that of Edmund Leach among the Kachin. The final section is devoted to chaos theory and fractal geometry. Considering social processes as “complex dynamical systems”, the kind of processes from which chaos theory developed, I draw on a number of anthropological analyses, mainly from Melanesia and Amazonia, to highlight the usefulness for anthropological thinking of notions such as non-linearity, system attractors, self-similarity and non-integer dimensionality. Each section ends with a commentary on analytical shortcomings that are addressed in the following one, so as to establish a progression of increasing congruence between anthropological analysis and social processes.

## Experimental measuring vs engineering black-boxing

No one would dream of making an experimental contribution to physical or chemical science, without giving a detailed account of all the arrangements of the experiments; an exact description of the apparatus used; of the manner in which the observations were conducted; of their number; of the length of time devoted to them, and of the degree of approximation with which each measurement was made (Malinowski, 2002 [1922]: 30).

Malinowski's introduction to the *Argonauts of the Western Pacific* is devoted to the ethnographic method. It is written against the background of previous unscientific reports and in contrast to the observations of other white men who are not scientists yet may have contact with indigenous peoples. As Durkheim would do for sociology, Malinowski wanted to renovate anthropology, which he understood required an upgrade in its rigor. He believed that the natural sciences provided a clear model of how to advance in the legitimate production of knowledge and presented a number of methodological recommendations as steps in the pursuit of an ideal of objectivity: separating fact from interpretation; collecting all material from the conventional to the outlandish; considering the role of emotions to gauge the quality of the ethnographer as observer.

If we may see an aspiration to infuse the social with the positivistic principles and standards of the natural sciences, it is no less true that the "natural sciences" include a wide range of fields, practices, and methods. From this array of procedures Malinowski seems to model ethnographic reporting as an exercise in measurement, which makes the ethnographer an instrument for conveying an accurate portrait of reality. Though reality is not subject to quantification, to metaphorize ethnography as a measuring exercise infuses it with a quantitative ideal: hence the emphasis on precision and the avoidance of interferences that may affect accuracy.

All measuring devices must be designed to minimize alterations in the amount they are trying to quantify. There is no point in measuring the flow of a liquid or electrical current, for example, with something that will significantly change that flow. Instruments also require calibration and must be built to retain a constant sensitivity throughout a given range of measurements. All these features can be identified in Malinowski's methodological guidelines for ethnographic fieldwork. Minimum disturbance by the ethnographer/measuring device should be the result of co-residence, when the anthropologist's presence "soon adopts quite a natural course very much in harmony with his surroundings" (2002: 37). Calibration of the instrument is what the "transparency" of participant observation, the sharing of the feelings of the natives, hopes to achieve (2002: 58). And the advice to maintain an equal focus on the everyday and commonplace as on more singular events is analogous to keeping the sensitivity of a device constant throughout the range of possible measurements.

Of course this ideal of objectivity, which pictures the anthropologist as a "sensor" of another's culture has long been criticized. The anthropologist's culture, and dialogic and power relations with natives, and the general character of the anthropological project are recognized to have a much more nuanced and complex place in the production of knowledge. But it is nonetheless true that however aware we may be of the part we play in "observing facts" and seeing "their" connections with other "facts", we still perceive a part of our phenomenal experience as "facts" and other parts as operations on those facts. We do not need to buy into Malinowski's epistemological assumptions or aspirations to consider his guidelines as sound advice.

But the comparison I wish to make hinges somewhat intuitively on the value of change within a given method. If for the ideal of reproducing or representing another's reality faithfully, change or alteration – say between that reality and its representation – is something to be avoided or reduced to a minimum, there are other engineering and indeed anthropological methods where the place of change is very much the opposite. Change is a necessary feature that enables the modeling of a system.

## Engineering and structuralism's black box approach

A common task for an engineer – or at least a student of engineering – is to provide a model for a system the components and workings of which one doesn't yet know. This basically involves characterizing the system, initially identified as a “black box”, since we don't know what it is made of, by means of testing what kinds of operations the system applies to its input.<sup>1</sup> The idea is to map how the inputs are transformed by the system by registering the outputs generated by a set of controlled inputs. The “map”, the knowledge that input “ $x_1$ ” becomes “ $y_1$ ”, “ $x_2$ ” becomes “ $y_2$ ”, and so on, describes the system basically by what it does, how it transforms “Xs” into “Ys” (think of an amplifier that transforms electric voltage into sound volume in direct proportion for low frequency sounds, and dampens them for higher frequency sounds like a buffer speaker). This map of relations is called a transfer function.

This of course involves nothing more than finding an equation that represents the relations between Xs and Ys of the type we all learned in school,  $F(x)=y$ , and put in terms of a process, where Xs are inputs to a system and Ys are its outputs. This method of creating models for a system, which often serves the purpose of learning how to control it, shifts the focus from trying to find out what the black box is, to focusing on what it does. In other words, we are satisfied with knowing *what the system does*, and for all modeling purposes this is *what it is*. A description of what a system does, is always a way of knowing how the system responds to different events or changes in the environment where it is inserted.

Now if to return to ethnographic reporting and anthropological theorizing, it is not hard to see how structuralism's emphasis on relations more than terms; on systems more than institutions; on model building, experimentation and comparison; on function understood not as utility (as Malinowski would) but as dependency between variables; can be understood to be modeled less on experimental measuring and more on system-characterization through transfer functions.

Lévi-Strauss's requirements for “structural models” imply the assumption of culture -- or a domain like kinship or totemism -- as a black box, subject to being modeled by a transfer function. A good structural model is “made up of several elements, none of which can undergo a change without effecting changes in all the other elements” (1963: 279). A good model should also predict what these changes would be, and the sum of these changes in the model should constitute a transformation group. (Ibid.)<sup>2</sup>

Analysis in anthropology and engineering, in this view, involves a similar art: observing facts and elaborating “methodological devices which permit the construction of models out of these facts” (ibid.: 280) -- like determining what are the right inputs and outputs -- to then be able to “experiment on models”, that is, discover a “set of procedures aimed at ascertaining how a given model will react when subjected to change and at comparing models of the same or different types...” (ibid.) -- which is like establishing the transfer function of a system.<sup>3</sup>

Perhaps the best examples of the fruits of this method can be drawn from Lévi-Strauss' discussions of totemism and kinship. In the first case, the “methodological device which permits the construction of a model” steers away from totemic animals themselves, the terms, and considers as inputs to the system the difference between pairs of terms, so that a series of natural differences can be mapped onto a series of cultural differences.

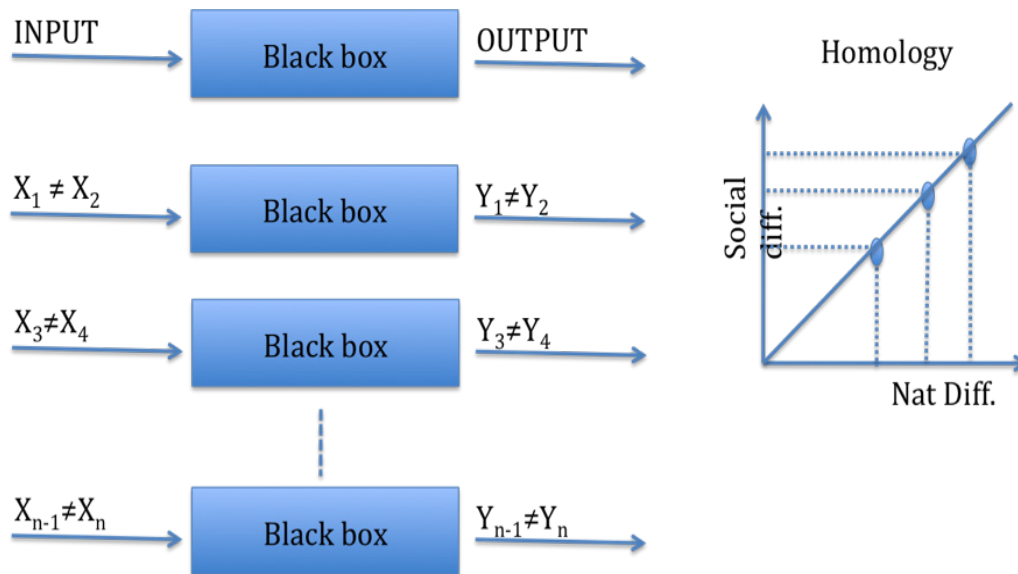
1 “The terms “black box” and “white box” are convenient and figurative expressions of not very well determined usage. I shall understand by a black box a piece of apparatus, such as four-terminal networks with two input and two output terminals, which performs a definite operation on the present and past of the input potential, but for which we do not necessarily have any information of the structure by which this operation is performed. On the other hand, a white box will be a similar network in which we have built in the relation between input and output potentials in accordance with a definite structural plan for securing a previously determined input-output relation” (Wiener, 1985 [1948]: xi).

2 Given that the subject of group theory in Lévi-Strauss's structuralism has been described and analyzed brilliantly by Mauro Almeida (1990) I will not discuss it here and refer the interested reader to Almeida's paper.

3 These methodological similitudes are, of course, not surprising, given Lévi-Strauss's interest in developments within mathematics as well as communications, game and cybernetic theories (see Lévi-Strauss, 1963 and Almeida, 1990).

The totemic transfer function is basically a relation of homology that converts natural differences into cultural ones in the form  $X_1 \neq X_2 :: Y_1 \neq Y_2$  where Xs are natural species and Ys social groups, like clans.

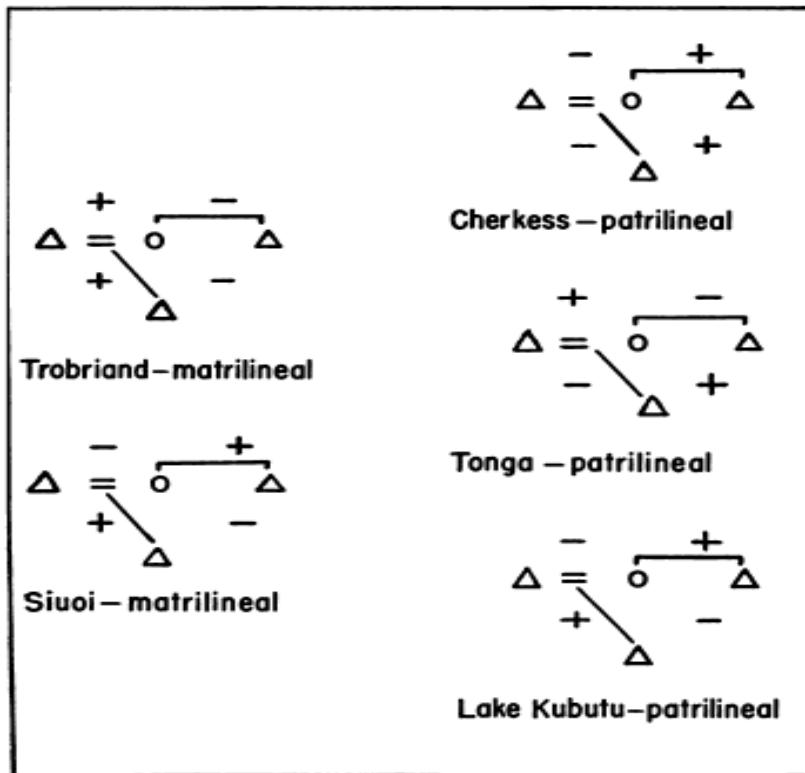
Figure 1. Totemic transfer function: Homology



Suppose Xs are natural species and Ys are clans. The transfer function is a series of homologies between natural and social differences.

In the case of kinship, in *Structural Analysis in Linguistics and Anthropology* (Lévi-Strauss, 1963) Lévi-Strauss' discussion with Radcliffe-Brown focuses on the latter's incorrect selection of an appropriate "methodological device" for building a structural model. Whereas Radcliffe-Brown only considers the relationships father/son and uncle/sister's son and maps them onto patrilineal and matrilineal systems, Lévi-Strauss considers four relationships -- brother/sister, husband/wife, father/son, and mother's brother/sister's son -- as constituting a system and hence he maps them onto each other to find out which relations remain constant among the relationships in a number of cases he examines, (see Fig. 3). Additionally, whereas Radcliffe-Brown considers the nuclear family to be "elementary", Lévi-Strauss' "atom" includes the crucial affinal relationship that links "elementary families" in the first place. Considering this more extensive set of relationships, Lévi-Strauss is able to account for a broader range of variations of an elementary kinship structure. This is like determining a transfer function whose inputs are the above four relationships and outputs are the relations between these relationships, which always satisfies two conditions: a) that "the relation between maternal uncle and nephew is to the relation between brother and sister as the relation between father and son is to that between husband and wife" (ibid.:42); and b) "[The] structure rests upon four terms (brother, sister, father, and son), which are linked by two pairs of correlative oppositions in such a way that in each of the two generations there is always a positive relationship and a negative one." (ibid.: 146).

Figure 2: kinship variations (Lévi-Strauss, 1963: 45)



The structural method does not eliminate the need for observation of ethnographic facts. Indeed, there is nothing germane to it that invalidates or is incompatible with Malinowski’s fieldwork recommendations. Lévi-Strauss affirms that observation and experimentation are two steps in the process of structural anthropology. “Observation” is thus still marred by the problems of measurement: reducing the observer’s impact on the measure itself -- we could say that we still need “sensors” to register inputs and outputs of models. “Experimentation”, on the other hand, is all about change; it needs change to see what the black box does, how it reacts, this being the essence of describing it, of finding its transfer function.

But what if the requirements of the “black-box method” were also those of measurement? It is not far-fetched to think that in the different ways anthropology has become more “reflexive”, “dialogical”, “post-social” and “ontological” it has allowed the changes and perturbations necessary for the structural “experiments” to imbue the “measurement” phase of enquiry, making the impact of the observer something other than a nuisance or error to be reduced. Of course, this does not mean the ethnographer is purposefully going to wreak havoc among community members. It means that, if the specific relationships that anthropologists build with the people they study involve something other than an authoritative representation of reality -- as emphasized during the “crisis of representation” -- if ethnography is not the measurement of events and their correlation with cultural symbols, it can be seen rather as an exercise in relating anthropological and native symbols, concepts and/or models (see Wagner, 1967). The implications can be stated in different ways: that the thing being measured and the measuring device (say culture) are of the same kind (see Wagner, 1981, Viveiros de Castro, 2002); that ethnographic reportage is necessarily an exercise of describing foreign concepts in our own terms (see Strathern, 1987); that we do not know in advance what our object is, that it is a blackbox, the study of which might alter the very concepts we use to describe it, betraying our own language in the translation, as the ontologists have affirmed (see Henare et al., 2007).

If we can envision anthropology as the study of culture through culture (*sensu* Wagner, 1981) the reflexive and progressive adjustment of the relations between native and anthropological symbols during fieldwork and ethnographic writing must also be a general feature of culture. This means that if the assumption of a system that can be modeled is to be upheld, it must include a feedback loop. That is, if our system relates inputs and outputs, the latter affect the former. Consider Sahlins' (1985) well-known discussion of structural transformation: in using cultural categories to interpret reality, this process extends the meaning of those categories and may further alter the relations between them.

This brings us to our second mathematical/engineering image and its relation to anthropological modeling: that of a system with a feedback loop. But before we get there, a final comment on the black box method and the recent term "black-boxing", as coined by Actor Network Theory (ANT).

The reader of Latour will be familiar with the phenomena of "black-boxing" whereby "scientific and technical work is made invisible by its own success. When a machine runs efficiently, when a matter of fact is settled, one need focus only on its inputs and outputs and not on its internal complexity. Thus, paradoxically, the more science and technology succeed, the more opaque and obscure they become" (1999: 304). Now the ANT method of "feeding off controversies" Latour advocates for destabilizing settled social sciences concepts like "social" and "society" (see Latour, 2012), is very much the engineering black-box approach just described. It may sound paradoxical, but the way to uncover the complexity made invisible by black-boxing is to treat the phenomena itself as a black box, reverse engineering the (black-box) effect with the (black-box) method. Consider the following extracts from *Reassembling the Social*, a recent exposition of the ANT program.

Sociologists of the social like to appeal to 'social inertia', as if there existed somewhere a stock of connections whose capital could be eroded only over a long time. For ANT, if you stop making and remaking groups, you stop having groups. No reservoir of forces flowing from 'social forces' will help you. *For sociologists of the social, the rule is order while decay, change, or creation are the exceptions. For the sociologists of associations, the rule is performance and what has to be explained, the troubling exceptions, are any type of stability over the long term and on a larger scale. It is as if, in the two schools, background and foreground were reversed* (Latour, 2012: 35, emphasis added).

The reason for this difference in duties is that, in the eyes of the former group [sociologists of the social], the choice of a departure point is not absolutely crucial since the social world already exists. For them, if you highlight 'classes' instead of 'individuals', 'nations' instead of 'classes', 'life trajectories' instead of 'social roles', or 'social networks' instead of 'organisations', all the paths will merge in the end since they are simply somewhat arbitrary ways to delineate the same big animal—in the same fashion as for the proverbial elephant seized successively by the leg, the ear, the trunk, or the tusk. However, the situation is entirely different for ANT because neither society nor the social exists in the first place. *They have to be retraced by subtle changes in connecting non-social resources.* Thus, every choice of a departure point will lead to the drawing of a completely different animal, fully incommensurable with the others. (Ibid.: 35-36, emphasis added)

## Feedback in Bateson and Leach

Feedback refers to how outputs are fed back into a system and become part of its inputs. The notion is particularly present in the study and design of control systems, where an engineer is interested in either describing the way a system regulates itself or in the design of mechanisms to control a system. In both cases, s/he may begin by assuming the system as a black box, figuring out its transfer function and then learning either how feedback loops effect appropriate self-regulation or which feedback loops would be necessary to control the system from the outside.

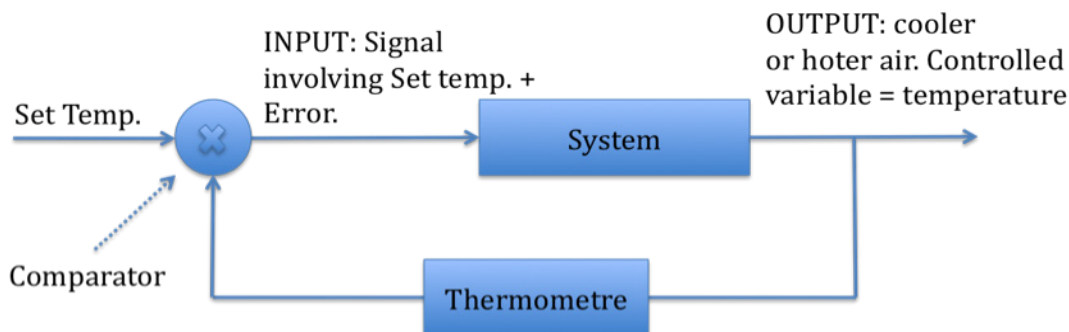


The ways in which information flows within a system and between itself and its environment, and the controlling function this flow can have over the system is the essence of the study of cybernetics.<sup>4</sup> In the broadest of terms, feedback can be negative and positive. If we can think of a system as having a goal or objective (like air conditioning keeping a room at a given temperature, or electro-mechanic servos keeping a drone in a stable position in the air), the system needs information about how well or bad it is achieving the goal. This information must be fed back into its inputs to correct the output and approximate it to the goal or keep it within an acceptable margin of error. This kind of negative feedback generally involves one or more sensors that provide the information about the error -- the difference between the current state of the output and the desired one -- which is fed back as input, to minimize the error, considering a given goal. A positive feedback augments the error of the output and can lead the system to growing states of instability. For this reason it is generally undesirable from the point of view of control.

Think of picking up a plastic cup of water from a table. Your hand, arm, eyes, and brain work together to achieve the goal. But this involves moving your hand in the right direction, at the right speed, stopping at the right moment and applying the right pressure on the cup so you can hold it without crushing it or letting it slip out of your hand. This entire process requires sensing how well you are doing the job and feeding that information to the brain so it can control the mechanics of picking up the cup.

Think now of the air-conditioning in a classroom: you have a remote control with which you set the temperature you want in the room. The machine switches on, either cooling or heating the air, and stops at some point, when its sensor, a thermometer, feeds back the information that the desired temperature has been reached. After a while, the room's temperature changes beyond a given designated limit, that information is fed back to the air-conditioning and triggers it on again (see Fig. 3).<sup>5</sup>

Figure 3: Negative feedback, air conditioning device example



Now the idea of self-regulation and the circularity of cause and effect it involves, has obvious resonances with social dynamics. The recursiveness through which past states of affairs influence present ones is intrinsic to social processes in so far as they are all time-dependent. We may learn much from any synchronic analysis that eliminates the need to consider a longer length of time, but even this kind of approach needs the passage of time to register sequences of acts and a range of “micro-changes” that allow the depiction of an adequate snapshot of the state of a ritual, social organization, language or culture.

Perhaps the most explicit example of the notion of feedback in anthropological analysis is found in Bateson's study of the Naven ritual among the Iatmul of Papua New Guinea, particularly his discussion of schismogenesis, which he defined as a “process of differentiation of behavioral norms resulting from the

4 Norbert Wiener's famous book is in fact entitled “Cybernetics: or control and communication in the animal and the machine” (Weiner, 1961 [1948]).

5 It should be noted that within the range of control systems, this ON-OFF method, is perhaps the crudest.

cumulative interaction of individuals” (1958: 175). The idea is intrinsically recursive and systemic because it requires that we see “the reactions of individuals to other individuals’ reactions” (ibid.). Bateson identified two basic forms of schismogenesis. Symmetric schismogenesis involves two individuals or groups reacting to each other’s behavior with a similar behavior, like the response to boasting with more boasting that characterizes competitive rivalry between men or groups of men of different patrilineages among the Iatmul. Complementary schismogenesis involves a differentiation between the parties by responding to a cultural behavior with a complementary one. Bateson’s examples were women’s submissive reactions to the assertive behavior of men, but also the submissive reaction of novices to their assertive initiators in the male initiation ritual. Both these types of schismogenesis are examples of positive feedback loops, where differences between the parties’ behavior tend to increase: boasting encourages more boasting and assertive behavior responded to with submission encourages higher degrees of assertion and further submission. While Bateson wanted to explain how differences between male and female ethos (culturally normative behavior) was created and sustained in relationships, the positive feedback inherent in schismogenesis quickly led to the question of how social groups didn’t simply breakdown due to the instability that ever-increasing differences, the unchecked positive feedback, leads to. His answer was that complementary and symmetrical schismogenesis worked as tendencies that compensate each other, in a self-regulating fashion, so that one form of schismogenesis counterbalanced the excesses of the other. In his 1958 epilogue, Bateson saw the need to find an explicit negative feedback loop that would, in different aspects of Iatmul life, exhibit this compensatory or self-correcting quality, and it was in the different inversions of male and female ethos in the Naven ritual and other combinations of symmetric and complementary behavior in initiation rituals where he found some of these mechanisms at work.

We could also think of Leach’s famous analysis of *gumlao-gumsa* political forms among the Kachin in terms of positive and negative feedback. Leach describes *gumlao* and *gumsa* as totally opposed forms of political organization - roughly as feudal/hierarchical and republican/egalitarian - and the Kachin as historically shifting from one form to the other due to the internal inconsistencies of the system they constitute. These contradictions can be cast in terms of the incompatibilities between principles of class and segmentary organization or in terms of the counterposed principles of rank and kinship. In any case, the *gumlao* egalitarian organization results from excessive social differentiation (positive feedback) in terms of rank at the expense of kinship. A *gumsa* Kachin chief who exaggerates the aristocrat-serf aspect of his social relations will provoke revolt and community fission by those very serfs who are also his kin. The new *gumlao* order restores the principles of kinship and reduces class differences to zero. This can be seen as a radical form of negative feedback -- i.e. kinship diminishing the difference created by rank. However, according to Leach, because the *mayu-dama* kinship organization implies a hierarchy of its own, *gumlao* Kachin lineages must either be arranged in a circle or tolerate the process of internal rank differentiation, whereby kinship and class hierarchies become aligned. Hence, it is a matter of time before a *gumlao* organization becomes *gumsa* again.

Leach sees both *gumlao* and *gumsa* as structurally defective and unstable, but the spirit of the analysis invites us to focus on a wider system that includes the Shan, which provides the model of political organization for *gumsa* Kachin.<sup>6</sup>

The system may appear unstable from the point of view of a single *gumlao* or *gumsa* community at any given moment, but viewed as a whole and over a wider historical period it is in stable oscillation, and hence self-regulated. External political and economic circumstances impinge on a system with a relatively stable Shan component and a Kachin component that swings from a Shan-like organization to its antithesis.

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<sup>6</sup> In contrast with the Kachin, the Shan appear stable and in part this is because, contrary to what happens among the Kachin, the Shan did not have a segmentary organization, because their principle of “structural continuity” is not “clanship and affinity”, but “land holding” (Leach, 1954: 214). It is because some Kachin chiefs strive to emulate Shan princes and political organization, that contradictions between politics and kinship arise among the Kachin in a way that doesn’t occur among the Shan.

It is interesting to note that in Leach's final remarks on *gumlao/gumsa* oscillation, we find many terms common to the kind of engineering approaches we have been describing: "structure", "disturbance", "environment", even if no mention of feedback or self-regulation is actually made.<sup>7</sup>

The ultimate 'causes' of social change are, in my view, nearly always to be found in changes in the external political and economic environment; but the form which any change takes is largely determined by the existing internal structure of a given system. In this case, the *gumlao* order and the *gumsa* order are both unstable; in situations of external disturbance the tendency is for *gumlao* systems to turn into *gumsa* and for *gumsa* systems to turn into *gumlao* (Leach, 1954: 212).

Implicit in Leach's remarks is a notion of a system's robustness or resilience, that is, its ability to self-correct despite external disturbances. Levi-Strauss (1966 [1962]), when discussing the logics of totemic transformations (in chapter II of *The Savage Mind*), also appeals to negative feedback in noting the resilience of totemic systems to reestablish their formal systemic qualities if demographic factors don't knock them too far out of balance.

A resemblance is also seen between Leach's analysis and Sahlins' mentioned above, the former in terms of social change and structure and the latter's in terms of cultural change and structure. We could say that as "political forms" are lived out, they are transformed in a way similar to how Sahlins understands the transformation of symbolic categories in their application to reality. In both cases, there will be a range of "external disturbances" that the system can cope with and assimilate like a shock absorber. Beyond a certain limit, however, the error correcting tendencies of the system are not enough and structural change follows.

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So far we have seen how the black-box method of mapping relations of input and output provides a good description of a system in terms of what it does, and that by modeling such systems with different forms of feedback we can picture the recursiveness we find in social processes. This modeling exercise is also based on registering how a changing environment impinges on the system and hence is attuned to a view of culture as being in continuous transformation, and analysis requiring both synchronic and diachronic lenses.

However, there are some drawbacks to the method. Considering our examples, we may ask whether feedback is not too ample a notion, where any two contrasting behaviors, cultural norms or principles of social organization may be modeled as being in a counterbalancing loop; the problem was posed by Bateson himself, but I think it remains an issue. It is also true that the idea of self-regulation or control of a system implies that it has a goal or objective and this, of course, re-introduces the problem of teleology for which the functionalists were rightly criticized. However broad, abstractions such as social reproduction, survival, adaptation, or equilibrium presuppose entities like "society" and "culture", which are hard to imagine as agents of management or objects of control.

If asked what the goal of the system might be we can conjure these possibilities -- adaptation, balance, self-preservation -- or venture others when we consider power relations internal to the system: the control of the means of production; the control of women by men; elders' control of youths; the control of scarce human labor via the control of women's reproductive capacities. The truth is we have no good answer to what is being regulated in self-regulation. The system metaphor begs the question of what a system is doing when it is relating all its variables. Would it be possible to think of a goal-less system or self-regulation without the self; that is, keep the method and drop its functionalist drawbacks? This is one way to see what Roy Wagner

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<sup>7</sup> This is no surprise considering that Leach was initially trained as an engineer.

has done in *The Invention of Culture* (1981).<sup>8</sup> Wagner's semiotics substitutes the distinction between symbol and referent with two symbolic modes: conventional and differentiating symbolization. In this view, cultural symbols lose their controlling hold over reality and we come to see all action and thought as a process in which the ordering effects of conventional symbols are in dialectic tension with the particularizing effects of differentiating symbols. This is an ecology of symbols where any distinction between an ordering system and its outer environment is an illusion, an artifact of native cultural convention or anthropological analysis.

## Chaos and fractals

One recent turn in the natural sciences in the past decades has been the development of "chaos theory". This theoretical corpus has been increasingly applied to natural phenomena and processes that were previously very difficult to model, due to their apparent randomness, disorder, and unpredictability. A cover term for these processes is "complex dynamical systems" and they include such things as weather patterns, turbulent flows of fluids and population dynamics. As the term and the description suggests, the kind of problems chaos theory attends to are not unlike those that anthropology is well versed in. Who would disagree that social groups are "complex," "dynamic" and to different degrees "systemic", or that they exhibit a combination of pattern making with a degree of randomness or unpredictability? Chaos theory addresses many processes at a human scale, and in contrast to other scientific theories that have called the attention of social scientists like relativity and quantum mechanics -- the first devoted to the very big, the second to the very small, and both beyond the reach of human experience -- constitutes a type of return to the "logics of sensible qualities" as Lévi-Strauss would have it (see Mosko, 2005: 8). For all these reasons, it is worthwhile for anthropologists to take a look at chaos theory.

Many features characterize chaotic phenomena. I will address only a few of them here, some just to note their resonance with social phenomena, while exploring others in more detail with specific ethnographic examples.

## Non-linearity

A linear system is one in which the outputs are proportional (directly or inversely) to the inputs. A non-linear system is one that does not have this proportionality; outcomes change in ways that are not proportional to inputs. Of course, most systemic processes in the world are non-linear, but mathematicians and engineers have developed methods to "linearize" them, that is, simplify the mess, making approximations to simpler models for the system, restricting its description to the range of its stable functioning. As far as we can understand ethnographic reportage as a "snapshot" of an ongoing human process, and all structural model building and theoretical generalizations as simplified versions of the real thing, they are also forms of linearization that "work" to some degree.

But think of the most simple description of meaning-making through language. When someone says "dark" you understand something literally or metaphorically obscure, the night or a complicated explanation. But if I say "bark" you will think of a dog or a tree. A simple change in one phoneme, /d/ for /b/, makes a big difference in the meaning of what I said. It is not hard to notice that making sense (meaning) is a non-linear process.

In the wider scope of our discussion, we have presented black boxes as systems that relate input and output variables in a kind of map that showed us what the system does. We saw that forms of positive and negative feedback could improve models of social processes because they better represent the recursiveness

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<sup>8</sup> It must be noted that Wagner draws inspiration for his *magnus opus* from both Bateson and Lévi-Strauss, innovating on their approaches, and blending their spirit.

of social life and describe forms of self-regulation and historical processes. Non-linearity allows us to make room for the fact that the system changes itself as it “does” all this relating. Think again of Sahlins’ structural history where social reproduction implies social transformation. Certain “happenings” are assimilated by the categories of culture and leave the relations between these categories unchanged. But other sequences of happenings, to the extent that they don’t fit nicely into the categorical cultural slots, provoke changes in the relations between categories. This is what Sahlins called “structural transformation”, which is similar to saying that the transfer function of the system is altered; that is, the system does not behave the same for the entire range of possible inputs/“happenings”. It is this kind of change that makes the equation between reproduction and transformation a nonlinear phenomenon.

### **Sensitivity to initial conditions**

Another characteristic of chaotic systems related to nonlinearity is their high sensitivity to initial conditions. This means that with a very small variation in the value of an initial input, the output will change disproportionately. A classic example is the so-called butterfly effect, which metaphorically expresses the high sensitivity of future states of the weather on earlier apparently unconnected conditions.

In anthropology we are surely aware of how slight differences in the “initial historical conditions” of social groups may lead these groups in different directions. As Mosko (2005) points out, we would normally call upon individual subjectivity, creativity, will, agency and choice to account for such variation. But his point is that this sensitivity is also characteristic of chaotic systems.

There is an interesting example of a “high sensitivity to initial conditions” in the ethnography provided by Carlos Fausto’s (2012 (2001)) study of the Parakana, a Tupi-speaking people living in the state of Pará in the Brazilian Amazon. The Parakana split due to an internal conflict around the 1890s. As a result, one group remained in their territory and another fled. A century later, Fausto described many differences among these two groups.

The western Parakana had no internal sociological divisions, no defined leadership position or political forum, and lived by foraging more than swidden agriculture. They had also developed a warring ethos, raiding enemy groups throughout the century, capturing numerous women from these enemy groups, which allowed them to develop a generalised polygamy. Relying on foraging for subsistence and raiding enemies for incorporating sociological difference, the western Parakana were a highly mobile “trekker” group. This eventually led them to run into an SPI (the Brazilian indigenist agency at the time) contact post and establish intermittent relations with whites, from which they obtained desired manufactured goods (like steel tools).

The eastern Parakana, meanwhile, were sociologically divided in two intermarrying moieties and three named patrilineal groups. They had a dual leadership model and a male political forum located in an external plaza. They lived less from foraging and more from agriculture, did not raid enemies, had a restricted, rather than generalized, polygamy, and were more sedentary and isolated from whites and other indigenous groups.

The western Parakana tended towards the kind of fluid and acephalous social organization associated in the regional ethnography with Tupi and Guianese societies, coupled with a socio-symbolic priority on otherness and the outside, as a source of productive internal differentiation. The eastern Parakana tended towards a more dialectical and closed-onto-itself organization, which in political and sociological terms is more akin to the central Brazilian *Gê* groups.

As Fausto queries the reasons for these important variations, what we find are really small differences in the initial conditions of the two groups upon fission. Differences like having a foreign captured child in one group and not in the other, for example, seem to have been important in making the eastern Parakana less warlike and mobile, while the lack of a degree of internal differentiation among the western group led them

to seek wives among enemies, which fomented a more mobile ethos as well as foraging. The development of moieties and self-closure in the eastern Parakana was favored by the fact that the fission left this group with a single kindred group focused on a group of siblings.

This is a very abbreviated account of all the minor factors that accumulated over time to increase the differences between the two groups, but it is enough to illustrate chaotic sensitivity to initial conditions. Moreover, it is quite remarkable to notice how a single ethnic group has the potential to develop in almost opposite socio-political directions. Finally, this study provides a historical account of what we could previously consider a transformation group (Tupi and Gê socio-cosmologies), only in terms of topological variation.

## Attractors

Attractors refer to the values of a variable towards which a dynamic system tends to evolve from a range of different initial conditions. Depending on the system, the attractor may be represented as a point, a curve, or a more complex n-dimensional manifold. A system such as a pendulum, for example, has a point attractor at its resting point. At whatever force with which the pendulum is initially set into motion, it will end up at the resting position after some time if no further force is applied. Following one of Mosko's (2005: 23) anthropological examples, we can think of cultural categories and their relations in Sahlins' analysis as an attractor of a cultural system whereby all happenings are interpreted through these categories. Even if happenings differ slightly from the categories that are used to interpret them, we may say that by guiding the interpretation, these categories, and the relations between categories, in effect "attract" the happenings to themselves. Leach's analysis of the *gumlao-gumsa* political forms may also be seen as a two-point attractor, that is, as states to which the Kachin political system will tend, oscillating in time from one to the other.

Serge Gruzinski (2002 [1999]) explicitly appeals to the idea of attractors when describing the relations between European and indigenous Mexican artistic forms during the early stages of 16th century colonization. Amid the demographic, social and political chaos resulting from the conquest, the European fable and the grotesque component of art constituted "attractors" that channeled lines of reconstruction and transformation within sectors of the newly hybridized (Indigenous-European) society. Whether it be along the lines of art, literature or even a city layout, Gruzinski's analysis shows, in my view, how the "savage" (sensu Lévi-Strauss) component of European and Indigenous Mexican thought constituted an "attractor"<sup>9</sup>, creating pockets of order, patterning, mutual interest and agreement in what Sahlins would call "working misunderstandings". These are privileged lines of interaction, along which, despite very different motivations for the interaction, the general advancement of each party's project allows for the satisfaction of mutual interests.

In my own analysis of relations between Yanomami and white doctors working among them (Kelly, 2011), I tried to show how a mutual interest in "civilization" has also worked as an attractor within an increasingly hybrid cultural landscape. Ever since the arrival and settlement of missionaries among the Yanomami communities along the Orinoco River, the civilizing project of missionaries was generally accepted and embraced by the Yanomami. However, this mutual interest was also a "working misunderstanding" because while missionaries' efforts to civilize were primarily motivated by efforts to "make society", that is, establish fixed conventions that would align the Yanomami with the State's desired forms of social, political, and economic organization, the Yanomami were motivated by their conventional efforts at "making people" or "making kin", albeit of a new hybrid nature. The gifts of manufactured objects and acquisition of new practices and knowledge like speaking Spanish, learning to read and write, eating the food of white people and using money were for the Yanomami forms of acquiring a new body, understood as an addition of new relational capacities with whites

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<sup>9</sup> That an attractor was constituted along artistic lines is Gruzinski's point; that it was also constituted along the "savage" aspects of art is my own reading of the descriptions Gruzinski provides.

and other Yanomami communities. For the missionaries, these were forms of preparing the Yanomami for their integration into the nation-state. “Civilization” was an attractor in this process insofar as it drew them together in an apparently common project which in fact helped to maintain their divergent motivations, “making people” vs. “making society”, relatively unnoticed. It was the partial overlap between efforts to make people and those to make society, that, as an attractor, fostered the creation of a region of understanding, agreement, and order, within a wider field of relations inclusive of dissonance, disorder, and disagreement. Nowadays, Orinoco Yanomami may contextually speak of themselves as “civilized”, yet what they mean by this -- having a hybrid Yanomami-white habitus as a result of historical transformations -- is quite different from what the doctors working at the community health posts, for example, understand as “civilization” -- which has less to do with a habitus and more to do with the upholding of conventions or rules enabling their harmonious co-existence and the smooth working of the health system in their communities.

### Fractal geometry

Fractals are among the mathematical objects that have recently caught the wider public’s imagination. Anthropology has also made use of the image of fractals to illustrate different qualities of social organization, personhood, ceremonial exchange, and such things as indigenous counting systems (see Wagner, 1991; Gell, 2006 [1999]; Kelly, 2001; Mimica, 1988). Among the different qualities of fractal objects, self-similarity, the indistinction of a part from the whole, and their non-integer (i.e. fractal) dimensionality have been drawn on in different anthropological descriptions. I will treat a few of these in turn.

Self-similarity refers to an object’s replication of a pattern at different scales and it is interesting to note its occurrence in many natural structures such as the shape of leaves, the form of a coastline, or the repeated branching of a river system. In anthropology, as Mosko (2005: 26) notes, we can think of Evans-Pritchard’s description of the Nuer political system in terms of segmentary oppositions as a case of social organization showing self-similarity at different scales.

A more explicit example comes from Gell’s (2006 [1999]) “reader’s manual” for Marilyn Strathern’s *Gender of the Gift*, where he depicts as fractal interlinking identities of gifts that flow in some Melanesian ceremonial exchanges. At every stage of an exchange trajectory, a gift objectifies “the donor’s capacity, not to produce pigs himself, but to elicit pigs from others, namely, partners further back the exchange path” (Ibid.: 48). So it is that in any given exchange, the pig being transferred objectifies the relation between donor and recipient, but the donor “encompasses” the number of similar previous exchanges within himself, which establishes the fractal self-similarity (see Fig. 4).

Figure 4: Fractal self-similarity in ceremonial exchange, from Gell (2006 [1999]: 49)

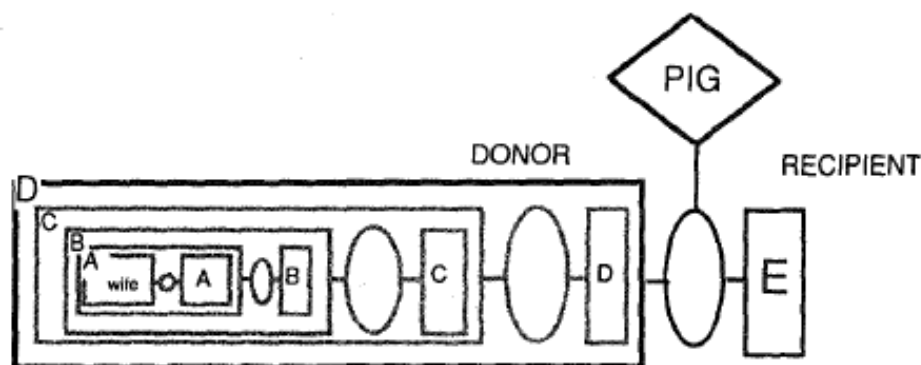


Figure 1.16

Another example is the self-similarity in the cascading bifurcations Lévi-Strauss identifies in some Amerindian myths. At every stage of the narration, one end of an opposing polarity becomes a new polarity itself, a pole at which the myth will continue to be told becomes again another polarity, and so on. The best example of this “perpetual disequilibrium” as Lévi-Strauss called it in *The Story of Lynx*, is the cosmogonic myth of the Tupinamba, where, for example, at one stage indigenous are opposed to whites, and at the next, the indigenous pole is divided into enemies and allies, and then the former, further divided into good and bad, and so on.<sup>10</sup>

One feature of fractals that should be noted is that, apart from a change in scale, the self-similarity of pattern means we cannot tell part from whole. One implication of this indistinction is that the conventional idea of the enumeration of parts that may add up to a whole, or their gathering to form a plurality, is not really applicable to a fractal object. This point was noted by Roy Wagner’s seminal *Fractal Person* (1991) where he shows how notions of oppositions between singular and plural, individual and group, part and sum -- which are all explicitly or implicitly conventional anthropological understandings of the individual, society and their mutual links -- are inadequate in the context of Melanesian sociality. This inadequacy is also evident in Strathern’s critique of the opposition of individual and society inspired by Melanesian ethnography (1988). In lieu of a language of individuals and groups, and of parts that add up to wholes, these anthropologists have appealed to other kinds of non-arithmetic operations like “obviation”, “eclipsing”, “replication”, “substitution/displacement”, “figure-ground reversal”, which don’t involve ideas of a singular opposed to a plural, or of enumeration and addition as the necessary link between the two. At the heart of these descriptions are metaphors of fractals that are more attuned to socialities where persons and relationships are not separated as terms and connections, the former being the creative agents of the latter. When Wagner writes:

A fractal person is never a unit standing in relation to an aggregate, or an aggregate standing in relation to a unit, but always an entity with relationship integrally implied (1991: 163).

And Strathern affirms:

In the way that Melanesians present social life to themselves, it would seem that there are no principles of organisation that are not also found in the constitution of the person (1992: 85).

the images conjured are incompatible with the conventional metaphors of society as an organism, machine, or system with its differentiated parts functionally integrated into some whole.

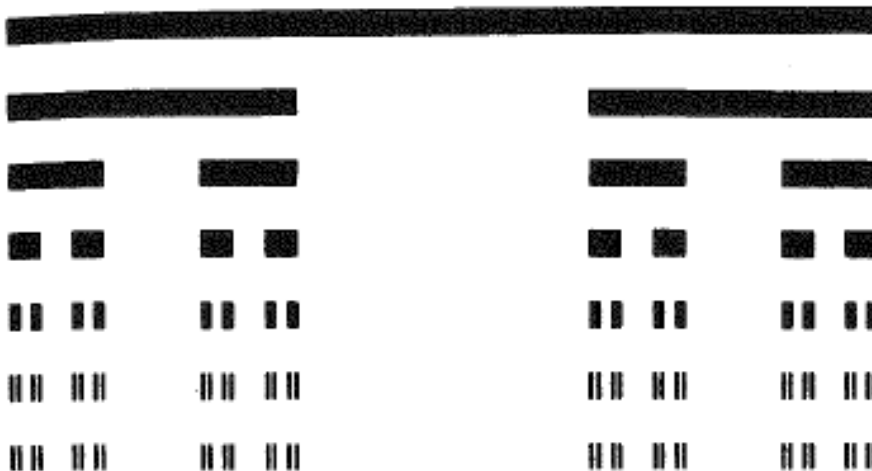
<sup>10</sup> For other analysis deploying fractal imagery see Carneiro da Cunha (1998) and Kohn (2013).



Of course the “one-many” form of considering the passage from unity to multiplicity is also implicit in the very anthropological, and now juridical, notion of multiculturalism. So long as cultures, societies, or groups are envisioned as analogous entities that can interact with each other, and that taken together constitute a plurality of different and partial perspectives on the world, nature or humanity, it is a one-many -- and not a part-whole -- mathematics that is implied (see Verran, 2001). As Gow says *a propos* a misunderstanding between a Piro Indian woman and a white school teacher, also a woman, in the Peruvian Amazon: we cannot simply assume this to be an encounter between two cultures or cosmologies, for this would determine the situation in the multicultural terms of the white teacher – there being two different perspectives of a singular and same thing -- predetermining, as opposed to querying, the nature of the exchange (Gow in Viveiros de Castro, 2002: 138).

What kind of image can we thus make of what we would normally call an inter-cultural relation? Perhaps we could begin with Wagner’s insight into the unexpected questions the Daribi posed to him while he was pursuing his own anthropological ones: “their misunderstanding of me was not the same as my misunderstanding of them” (1981:20). The “working misunderstandings” I have mentioned between Yanomami and white projects of civilization, with one drawn to “making people”, the other to “making society” is a phenomenon involving a two-way misunderstanding. We could say there are not one, but two, relations here, from Yanomami to white and *vice versa*, or Melanesian to white and *vice-versa*. But the point is that the two relations are connected, they are part of each other, and yet remain wholly distinct. Each is fundamental for the other to take its shape but they don’t mix or fuse. We could say this phenomenon has a fractal dimension, something between one and two (see fig. 8, the Cantor set of dimension 0.6), which must be part of what Strathern (2004 [1991]) wants to convey when speaking of “partial connections”.

Figure 5: Cantor set. You can intuitively project to infinity and picture that the dimension of the points that remain is somewhere between 0 and 1: more than a point but less than a complete line. Taken from Strathern (1991: 3)



This idea has been taken up recently by de la Cadena (2015) in her work with Peruvian shamans in the Andes. Describing her relations with her shaman friends during their collaborative ethnography she comments:

Intriguingly, in our case, this partial connection was composed of, among other elements, our shared and dissimilar condition as Peruvians. Our ways of knowing, practicing, and making our distinct worlds—our worldings, or ways of making worlds—had been “circuited” together and shared practices for centuries; however, they had not become one. In the circuit, some practices have become subordinate, of course, but they have not disappeared into those that became dominant, nor did they merge into a single and simple hybrid. Rather, they have remained

distinct, if connected—almost symbiotically so, if I may borrow from biology. Inhabiting this historical condition that enabled us to constantly know and not know what the other one was talking about, my friends’ explanations conversed with mine, and mine with theirs, and inflected the dialogue with our heterogeneity. I translated what they said into what I could understand, and this understanding was full of the gaps of what I did not get... On things that are partially connected, John Law writes: “The argument is that ‘this’ (whatever ‘this’ may be) is included in ‘that,’ but ‘this’ cannot be reduced to ‘that’” (2004, 64). To paraphrase: my world was included in the world that my friends inhabited and vice versa, but their world could not be reduced to mine, or mine to theirs. (Ibid.: 3-4).

## Conclusion

Although I have not sought to build or defend a particular argument, this article has shown the merits of an engineering black-box approach, its similarities with the structuralist method and certain improvements on the modeling of social life based on feedback first, and later on characteristics of chaotic systems, such as non-linearity. It has also dwelt on the potential of certain mathematical images, such as fractal objects and dimensions, for describing phenomena such as intercultural relations. This entire exercise hinges, nonetheless, on maintaining a notion of system, with its implications of pattern, regularity, and predictability. It is also imbued with a certain primacy of visualization in the way we have talked about mathematical “images” and “objects” as more or less fit for “picturing” or “describing” social phenomena. We can of course dismiss both these implicit principles as Euro-American biases, artifacts of analysis. A post-modernly inclined anthropology would inform us as much, and those like Strathern who have so much insisted on making these biases explicit, would stress the need for laying out our interests when engaged in description and analysis.

The way chaos theory allows for both patterning and unpredictability, for viewing complexity, not in contrast to, but as susceptible to generalization, at least makes the system metaphor something more palatable for these critical positions. But even then, one may still question; Is this not just a re-labelling of what we already knew? What new light has been shed by naming what has already been described? I myself have this feeling to some degree. And though I cannot offer ways to dispel this doubt, the approximation between hard and social sciences holds a certain premise (or promise?) of human and non-human similarity that has both a tradition and contemporary advocates. Gabriel Tarde, for instance, upheld this position against Durkheimian human exceptionalism, providing some of the roots for Actor Network Theory. The same could be said of Gregory Bateson’s systemic and ecological approaches, and their influence on Eduardo Kohn’s bio-semiotic “anthropology beyond the human” (2013). Moreover, the study of the anthropocene has pretty much forced us into transdisciplinary alliance-making -- which is also a stance that is an important part of Bateson’s legacy -- showing how much different disciplines may share underlying ontological assumptions that are inapt for living in the anthropocene, and how a “constructive interference” can suggest novel, more habitable futures, amid the anthropocenic ruins (see Tsing, 2019). But perhaps there is also something of a profound aesthetic motivation in this search, not unlike what Lévi-Strauss identified as being a running undercurrent of the Amerindian mythological corpus: a nostalgia for a time when humans and animals could communicate uninhibitedly.

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