SYSTEM DYNAMICS AND PROCESS PHILOSOPHY

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Abstract

System Dynamics involves two different conceptual components: a systemic component and a processual component. The second component has a crucial role both in System Dynamics practice and methodology. However, it has not received as much reflective attention in the System Dynamics literature as the systemic component. In this paper, we examine the peculiarities of this second component, and how it connects with the general tradition of process philosophy. To take into account that System Dynamics maintain strong conceptual connections with those different conceptual traditions is very important in order to achieve a better reflective understanding of the discipline, which would benefit both to practitioners and to theoreticians of System Dynamics.

Key Words: System Dynamics, System, Process, Structure, Behavior, Systemic Approach, Process Philosophy.

System Dynamics (hereafter, SD) involves two different conceptual components. One of them comes from the system tradition and it has been largely analyzed by many authors. It is the systemic component. The other component has to do with the dynamical and behavioral approaches adopted in relation to the systems under consideration. We can call it the processual component. The very expression "System Dynamics" reflects these two components.

Even though the second component has in fact a crucial role both in SD practice and in SD methodology, it has not received as much reflective attention as the systemic component. To see the peculiarities of this second component, and how it connects with the old tradition of process philosophy, would be very important in order to achieve a better reflective understanding of SD.

This paper has four main objectives. Firstly, we will introduce the tradition of process philosophy emphasizing its connections with SD. Secondly, we will make explicit a crucial tension between the tradition of process philosophy and the tradition of system philosophy. Thirdly, we will show how to pay attention to that contrast can offer new perspectives with respect to some very important old conceptual issues discussed in SD. We will argue that some of the problems involved in those issues could be much better faced from a process approach than from a mere systemic approach.

1. Process Philosophy

The tradition of process philosophy is much less known by the SD community than the systemic tradition. Let us offer a brief survey of it.

The entry "Process Philosophy" in *The Stanford Encyclopedia of Philosophy* begins as follows:

> "Process philosophy is based on the premise that being is dynamic and that the dynamic nature of being should be the primary focus of any comprehensive philosophical account of reality and our place within it. Even though we experience our world and ourselves as continuously changing, Western metaphysics has long been obsessed with describing reality as an assembly of static individuals whose dynamic features are either taken to be mere appearances or ontologically secondary and derivative." (Seibt, 2012)

We can say that the central claim of process philosophy is the following one:

> Processes are the ultimate building blocks of reality, in the sense that everything that exists has to be ultimately determined by some processes.

According to process philosophy, the concept of process has to be capable of providing the general categories of reality. Any other concept has to be derivate from the concept of process. This claim has the greatest scope. But in particular, it would have to be so with the concept of "object" and with the concept of "property". Objects and properties have to be logically constructed from processes. The same would have to happen with other concepts of the same family than the concept of object: substance, entity, individual, thing, etc. And the same would have to happen with all the concepts belonging to the same family than the concept of property: quality, feature, characteristic, relation, universal, etc.

Process philosophy is one of the most important research programs in philosophy. Its importance goes far beyond pure metaphysics or logic. To work out in detail the central claim of process philosophy has very relevant consequences in fields like applied ontology, epistemology, philosophy of science, semantics, philosophy of mind, philosophy of action, ethics, etc.

In a recent introduction to process philosophy, we can read:

> "Process philosophy has in recent years become one of the most particularly active and flourishing sectors of American philosophy. Though its antecedents reach back deep into classical antiquity, this doctrine as such is a creation of the twentieth century, in fact one of its most influential and interesting contributions." (Rescher, 1995, Introduction)

All the propositions expressed in this fragment are important. The classical antecedents of a process philosophy go back into classical antiquity. Moreover, they coincide with the very beginning of Western philosophy. Heraclitus is one of those antecedents. Many classical philosophers were looking for something maximally stable, placed beyond any change. This search is in sharp contrast with Heraclitus acceptance of change as the ultimate reality. Some of Heraclitus's sentences have become a *leitmotif* in process philosophy. We must recall, for instance, the following ones (Kirk, Rave, and Schofield, 2013):

> "No man ever steps in the same river twice, for it's not the same river and he's not the same man"
> "The sun is new each day"
> "All things are in flux"
> "There is nothing permanent except change"

Other important antecedents of process philosophy are Plato and Aristotle, in each case with a caveat. The Plato who is close to a process philosophy is the one who is speaking in the *Timeus*, and is trying to make sense of the changeable world of appearances, not the one who is simply removing all genuine reality and existence from that world. In turn, the process philosophy of Aristotle has to be looked for in his writings about natural philosophy, mainly about biology, not in his writings about the theory of categories and about logic.

The profound tension between processual tendencies and substantialists tendencies in the philosophies of Plato and Aristotle continues alive in Medieval thought. Process philosophy opposes to substance philosophy, being the last one the dominant paradigm in Western culture. Substance philosophy is based on the idea that the ultimate reality cannot but being constituted by something persisting across time. According to substantialism, change only makes sense through the exemplification and not exemplification of properties by something that has a more persisting and substantial existence. The tradition of process philosophy rejects this. According to it, change is the ultimate reality. Everything is in flux. There is no reality out of change. There are only different rates of change and some patterns of change having more stability than other ones.

In Modern philosophy, Leibniz is a very important reference in the tradition of process philosophy. It is specially relevant his conception of the ultimate constituents of reality as unextended points of active force, his "*monades*". In the line of the infinitesimal calculus invented by Newton and Leibniz himself, the whole of reality, and each particular entity, is understood as constituted by an infinite collection of such unextended points of active force.

After that, we have to mention the historicism of Hegel, and his discussions with Fichte and Schelling. It is a historicism with a strong ontological inspiration. The three authors rejected the Kantian notion of "*noumenon*", or "thing-in-itself". This is the limit notion of a reality constituted with complete independence of the subjects. According to these authors, that notion makes no sense. The important problem is to understand the processes through which reality comes to crystallize in different subjectivities and different objective realities. The discussion among Hegel, Fichte and Schelling was mainly about the possibility of a full explanatory understanding of those processes in "rational terms". In contrast with Hegel, Fichte and Schelling rejected that possibility. This discussion took place when modern Romanticism was originated. Both the tradition of process philosophy and Romanticism had a great influence in many authors, for instance in Nietzsche.

It is in the late 19th and 20th centuries when process philosophy had it maximal development. As it is indicated in the previously quoted Rescher's text, the most important cultural context of such a development was the context of American philosophy. The pragmatists Charles Sanders Peirce, William James, and John Dewey maintained very radical process approaches. In Europe, another important author was Henri Bergson. There are close connections between Bergson's ideas about the processual character of reality and the theses of Americam pragmatism. For all of them, the primacy of processes over substances had an epistemological motivation. Our only connections with reality come through processes of perception and through processes of action. Experience in general is a very complex process in which we cannot separate the "subjective" from the "objective". According to these authors, both notions are only abstractions.

After the rise of pragmatism, we have to pay attention to the figure of Alfred North Whitehead. He is very well known for his contributions to geometry and, in collaboration with Russell, for his contributions to logic and to the problem of the logical foundation of mathematics (their opus magnum is *Principia Mathematica*, 3 vols. 1910-13). In 1924, Whitehead moved from England to the University of Harvard. Among other things, he published there his seminal book *Process and Reality. An Essay in Cosmology* (1929). His processual approach had a great cultural impact in the United States, even in fields like theology. Most of the concepts and problems of recent process philosophy are due to Whitehead. As well as in the classical antecedents of process philosophy, and as well as in the debates among Hegel, Fichte and Schelling, the approach of Whitehead is not epistemological but, again, strongly metaphysic.

Whitehead tries to understand the ultimate nature of reality. According to Whitehead, reality is process. There is nothing more substantial. Even at the deepest levels, reality is a combination of processes. Moreover, even at the deepest micro-physical levels, reality appears to be only a combination of processes. The crucial question never is "What it is made from?", but "How it behaves?".

Another very relevant author of 20th century, also in the United States, embracing a process approach is Wilfrid Sellars. He was an analytical philosopher seriously worried about how to integrate the "manifest image" involved in our ordinary and intuitive ways of conceive the world, and ourselves in the world, with the "scientific image" coming

from natural science and technology. This was also a pivotal issue for pragmatists, for Bergson, and for Whitehead. There is however a very important difference. Sellars assumes a process approach only in the special field of the philosophy of mind. Here, the hard problem is to understand the nature of qualitative experience. Physical objects having physical properties are very different in kind from subjects having perceptual experiences of color, sounds, etc., or experiences of feeling a severe pain. According to Sellars, the only way to preserve the real, not merely fictional, existence of these last things is by postulating the reality of some primitive pure processes not constituted by physical objects having physical properties. Some crucial texts are Sellars (1963) and Sellars (1981).

Sellars's postulation of "pure processes" of experience in that sense is analogous to Donald Davidson's more recent proposal concerning the need to include primitive, or basic, "events" in our ontological domains in order to give an adequate logical analysis of propositions describing actions. Actions are events, and events are processes irreducible to objects having properties. The action to arise my arm, for instance, is not identical to my arm moving from some given position to another position. The action to arise my arm is an event. It is an irreducible process.

Many discussions in recent philosophy maintain close connections with the authors and issues we have mentioned. It is not possible to make reference to all of them here. But see (Vázquez and Liz, 2015). However, one thing is clear. Somehow, as Rescher indicated, process philosophy has become one of the most active and flourishing fields of the philosophy of our time.

2. A Tension Between Systems and Processes

Whereas the notion of "process" makes reference to changes through time, what can be called a behavior, the notion of "system" makes reference to something stable and substantial. Process philosophy always has rejected the irreductible existence of substances. From a process perspective, there would be no more stability than the stability of some dynamic patterns of behavior.

In SD, there is a confluence between the notion of system and the notion of process. In other more familiar terms, between structures and behaviors. But the relationships between both notions are not simple. See the analyses and discussions about this topic offered in (Davidsen, 1992), (Ford, 1999), (Forrester, 1983), (Graham, 1977) and (Richardson, 1995). See also the mathematical orientation proposed by (Aracil, 1986) and (Toro and Aracil, 1988).

Also, we have to distinguish between 1) the relationships between the notion of system and the notion of process in the context of formal models, i.e., mathematical and computer models, and 2) their relationships in the context of model building. About that, see (Forrester, 1994).

Let us explore a little bit the last distinction. It is very important in order to make clear how SD is conceptually connected with the notions of "system" and "process". In formal SD models, the structure goes first. A dynamic system is a mathematic object

obtaining a peculiar identity through a dynamic behavior across time. We have something substantial, a structure, and something processual, a temporal behavior. However, in formal SD models, mathematical as well as computer ones, the structure of the system has the most important role. For it is from the structure that a certain dynamic behavior is generated.

Things are very different when we are building the SD models. Here, the processual component is crucial. We know about the real systems through how they behave. Even the structural expert knowledges of the agents involved in the system, the so called "mental models", have to be contrasted and corrected with the help of the dynamical knowledge concerning the behavior of the system. About an interpretation of SD models as "points of view" that change over time through a variety of processes of interaction, see (Vázquez and Liz, 2011).

The above analyses show that SD is deeply connected with two traditions of thought. But only one of them, the systemic tradition, has been taken explicitly into consideration. The other one, the tradition of process philosophy, has exerted an implicit and hidden influence. This situation is quite odd. There is no reason to obviate in our reflections the great importance of process concepts in the practice and methodology of SD.

Let us go back. We have distinguished two different context in SD:

1. The context of description and explanation of the final formalizations of SD models.
2. The context of SD models building.

System concepts are very useful in the first context. When SD models have either a mathematical or a computational format, system concepts help to understand how a number of behaviors are generated from a certain kind of structure. However, the relevant concepts in the second context are mostly processual ones. In this second context, the primary concepts have to do with processes and behaviors. Here, system concepts have to be considered like a sort of abstraction. About the peculiarities of these two context, see (Alessi, 2000).

As we have said, in relation to SD models, the tension between systems and processes can be understodd as a tension between structures and behaviors. In our models, a structure has to determine univocally a behavior. But it is through differences in behavior that we come to know the structures of real systems. This is a very classic topic in SD literature. See, for instance, (Forrester, 1994), (Richardson, 1999) and (Sterman, 2000).

Moreover, according to process philosophy, it is through some behaviors that the diverse structures of reality come to be generated and maintained. Reality consist in a collection of processes of self-differentiation and restructuring.

SD involves both components, the structural and the behavioral, and the tension between them cannot be obviated. The important point is that we can put the emphasis

either in the structural (systemic) component, or we can put the emphasis in the behavioral (processual) component.

3. Old Issues, New Perspectives

To make explicit the processual component of SD offers new perspectives with respect to a number of very important conceptual issues. The following issues have been always powerful sources of problems and discussions. And it will be useful to see how an explicit process approach can offer new insights.

1. The Emergence of Novelties

The emergence of novelties in behavior is one of the most classical issues in the literature of SD. The very origin of SD is closely connected to the analysis of this phenomenon. In the 1950s, Professor Jay Forrester, engineer working at the MIT Sloan School of Management, showed through some hand simulations (mathematical calculations) that the instability in General Electric employment was produced not by external economic forces but by the internal structure of the firm. His results soon were applied to the analysis of the success or failure of corporations in general. This was the start of SD. See the interesting history compiled by (Radzicki and Taylor, 2008).

However, there are two very different ways to understand the emergence of novelties in the behavior of complex systems like socio-economic ones. We can understand it:

1. As making impossible the forecasting of behavior from a knowledge of the structure of the systems (plus knowledge of past history and of basal conditions).

2. As suggesting that it is not possible the forecasting of behaviors unless we take into account that part of the structures and behaviors of the systems are the result of human decisions and actions.

Even though it is always assumed that behavior is determined by structure, the emergence of novelties can be understood either in the sense of 1 or in the sense of 2.

Option 1 is the option favored by systemic approaches. Here, behavior is determined by structure, but the structural complexity of some systems, for instance socio-economical ones, generates radically new and non-predictable behaviors. Behavior is determined by structure, but it is not predictable from it.

In contrast, a process perspective would favor option 2. The main difficulty in predicting and controlling complex systems like socio-economical ones comes from the fact that important parts of their complex structure is due to human decisions, human actions, human ways of reacting to certain conditions, etc. Human actions are entangled with socio-economical processes. Novelty in the behavior of socio-economical systems does not come simply from complexity. It comes from the fact that we are part of that complexity.

In many cases, important parts of the structures of the systems modeled are the result of decisions and actions of which we are not fully conscious. In these cases, and they are the typical cases faced in SD modeling, forecasting is improved when we make explicit the dynamic consequences of those structural features.

2. Levels of Reality

That reality has a leveled structure is a very important topic in the systemic tradition of thought. SD has incorporated that notion. Moreover, talk about "levels of reality" is incorporated in our ordinary speech.

However, it is very difficult to make clear what is entailed by the claim that reality has levels. Again, there are two very different ways to conceptualize that claim:

1. Levels of reality as giving place to a number of ways of existing, or ways of having reality, very different in kind: the way in which physical phenomena exist, the way in which chemical phenomena exist, the way in which biological phenomena exists, the way in which psychological subject exist, the way in which socio-economical phenomena exist, etc.

2. Levels of reality are not different ways of existing, or different ways of having reality. Indeed, there are levels of reality. But, they are constituted only through differences in structural complexity. Biological phenomena, for instance, have more structural complexity than chemical phenomena. Simply, some phenomena can constitute proper parts of other ones.

There is a very important conceptual distinction between differences in existence (differences in the way of existing, differences in the ways of having reality) and differences in complexity giving place to a part/whole relation. In the first case, reality is plural. There are a number of different ways of existing, or different ways of having reality. In the second case, this does not make sense. There is only a way of existing, only a way of having reality. But, existing things, or real things, can be more or less complex.

One of the main reasons against 1 is the so called "problem of explanatory and causal exclusion". The expression was originally coined by Jaegwon Kim, some years ago, in the context of the philosophy of mind. The origin is the problem of how the mental can have any sort of causal efficacy in the physical world, but the result can be easily generalized with respect to any case of causation beyond physical causation.. To put it in a nutshell, the problem consists in that if there are different levels of reality in the sense of 1, and all of them are if fact supported by the physical level, or grounded in the physical level, then in the last instance there cannot be any other genuine causal efficacy apart from the physical causal efficacy. The physical causal efficacy excludes any other causal efficacy. Moreover, any causal explanation that is not a physical causal explanation has to be taken only as a useful fiction. See (Kim, 1993) and (Kim, 1998).

Option 2 does not requires different meanings , or senses, of existence. There is only one meaning, only one sense, in which we say that something exists, or that something

has reality. All differences come from the ways in which what exist is structurally organized.

Many times, systemic approaches have been tempted to adopt a leveled image of reality in which different sorts of structural complexities entail that the involved systems exist in very different senses. The existence of physical systems, for instance, would be very different from the existence of psychological systems, and also very different from the existence of socio-economical systems.

In the context of the philosophy of science, it has been also a very disputed issue the adequate way of understanding the relationships among the different scientific disciplines, from basic physical science to sociology or economics. Sometimes, the picture of a layered reality has received interpretations similar to 1. The problem of exclusion, both explanatory and causal, has motivated other interpretations closer to 2. Very recently, (Heil, 2003) has offered very sound arguments for a rejection of "levels of reality" in the sense of 1.

Processual approaches can assume much more easily option 2. In fact, many authors in the tradition of process philosophy have adopted option 2. All kinds of phenomena are understood as the result of processes of organization, and re-organization, taking place inside only one kind of reality. This avoids the problem of causal and explanatory exclusion. It does not matter whether the physical level is or is not the basic level. In any case, the basic level does not excludes anything because there is no other level of reality and existence apart from that basic level.

In other words, to identify different levels of reality in the analyses of complex systems does not entail the adoption of a non-reducible pluralist ontology. Methodologically, this has a very important effect: it liberalizes the use of "causal connections" among very heterogeneous variables. That heterogeneity would not be adequate from more orthodox ontological points of view. However, causal heterogeneity is one of the most salient and distinctive features of DS.

3. Generality/Specificity in Descriptions and Explanations

Descriptions and explanation in SD can be more or less general. Changing the perspective, we can say that they can be more or less specific. There is a deep tension between the general or specific character of our descriptions and explanations. Many times, the situation is one in which a decision has to be taken between two poles:

1. To adopt a "general" perspective. This would allow the applicability of the approach to other cases. However, there is a lost of accuracy in prediction and control. In particular, there is a lost of quantitative results.

2. To adopt a "specific", or detailed, perspective. Usually, this allows a great accuracy in prediction and control, with multiple quantitative results. However, the cost is a lost of applicability.

System thinking is typically inclined to pole 1. It offers conceptual tools to represent any phenomenon. In this respect, system language is analogous to the language of logic, or to the language of set theory. However, these advantages in descriptive power and explanatory scope are linked to a lost of accuracy in quantitative prediction and control.

The situation is just the opposite with process thinking. Its focus is the specific particularities of each phenomenon. Process thinking likes the minute details of a dynamical behavior. Because of that, it promotes the accuracy in quantitative prediction and control, even though there is a lost in descriptive power and explanatory scope. However, the emphasis on the "specificity of each process" is a very important antidote effect for the speculative tendencies of systemic approaches

The above tension between 1 and 2 is present in many methodological discussions in the SD community. Option 1 appears to be quite appropriate in educational contexts, when teaching SD. Option 2, in turn, appears to be quite appropriate when SD is applied to find solutions for real problems.

4. Normative and Evaluative Generality/Specificity

The tension between generality and specificity also affects to the normative and evaluative results obtained in SD modeling when the question is what to do, or what decisions to adopt. Here, the two poles are the following:

1. To assume certain given boundaries in the definition of the phenomenon analyzed, so that the normative and evaluative results are always "framed" inside them.

2. To consider any such boundaries as merely conventional, or as having only a "temporary and unstable" character, so that to achieve an adequate perspective always requires to "transcend" them.

A brief quote from Heraclitus, the most classical author in Western process philosophy, will show the difference between these two poles. He claims:

> "To God everything is beautiful, good, and just. Humans, however, think some things are unjust and other just."

Process philosophy takes very seriously the temporal, and hence very contingent, nature of every norm and value. It is placed very close to pole 2. Moreover, its aim is to "transcend" any boundary. The business of system thinking, in contrast, is to identify systems through change. It looks for the "boundaries" among systems.

There is another very important feature of the perspective offered by process philosophy. It locates in human beings the main source of norms and values. As Heraclitus says in the previously mentioned text, "Humans think that some things are unjust and other just". From a processual perspective, norms and values appear as the result of human decisions and actions.

However, we have to distinguish sharply this position from any relativist position. By itself, that norms and values are the result of decisions and actions does not entail any sort of relativism. As pragmatists claimed, what it suggests is that the source of norms and values can be under our control.

5. Realism

The last issue we want to discuss concerns realism. There are many discussions in SD about this topic. Mainly, there is a divide among:

1. Positions wanting to interpret SD models in a strongly "objectivist" sense, according to which some parts of reality would have the structures postulated in our models with complete independence of our modeling in those ways.

2. Positions recommending much more "moderate and relativist" interpretations, according to which the only thing we can say is that our models are very useful, both practical and theoretically, for dealing with the systems that are modeled.

Many times, this contrast is described using the distinction introduced by Hilary Putnam (who recently passed away) between a "metaphysical realism" and an "internal realism". Other authors, for instance Richard Rorty, make a difference between "Realism", with a capital "R", and "realism". About a philosophical interpretation of SD according to the distinction between a metaphysical realism and an internal realism, arguing that the second one is more adequate to understand the realistic compromises involved in SD, see (Aracil, Vázquez, and Liz, 1995) and (Vázquez, Liz, and Aracil, 1996).

In any case, it is clear that whereas the systemic component of SD tends to favor 1, the processual component of SD tends to favor 2. The first component needs to identify systems, with their sub-systems and super-systems, with their structural elements and relations, etc. This identification has to be done in a minimally stable way. And independence from modeling is a direct form to guarantee such stability. The processual component, in contrast, focuses on dynamical behaviors and in how we can forecast them and control them. It emphasizes the modeling activity as an endless process in which, through multiple interactions between subjects and reality, something is achieved.

We can say that the systemic component of SD is very substantialist. And that the rejection of all substantialism constitutes the main thesis of the other component of SD, the processual one.

There is something more to be said. Something that places processual approaches in a certain position of conceptual advantage. They offer a very plausible way of understanding why internal realism, or realism without capital letters, may be the more adequate position to follow. Let us finish our reflection with this point.

The adequate reason for internal realism would not be that all reality is some kind of human construction, or something like that. This is clearly a relativist claim. But, we can resist relativism. Moreover, we do not need to adopt it. Relativism is not the only way to assume internal realism.

We can assume internal realism simply because our knowledge of reality has a highly interactive and temporal nature. We can assume it because knowledge is not a state but a process, and a very complex one. About that, see (Liz and Vázquez, 2015).

Among the conditions in which the behavior of a system is generated, SD pays a very special attention to the behavior produced through the mental models, decisions, and consequent actions, of the agents involved in the real systems that are modeled. In these cases, the reality of the systems is dependent on some subjects. Moreover, the ultimate reality would be the complex net of relationships between the systems and the agents.

A systemic approach makes pressure about the need to take epistemological decisions about the "objective" and "subjective" character of the structures postulated in the models. In contrast, a process approach avoid that anxiety.

There is no need to take epistemological or methodological decisions about the realistic or non-realistic attitudes that we must adopt with respect to SD models. The lemma would be: Let things go! Perhaps, this is the best conceptual contribution of process philosophy to SD.

5. Conclusions

SD has been always very sensitive to the concepts coming from the "system tradition". However, SD has other conceptual component not less important. It has to do with the dynamic character of the phenomena approached. SD focusses not only on the structural components of systems but on how a behavior is generated from those structures in some given conditions. That processual component has been much less emphasized than the systemic one. However, it is very important in order to understand SD. Furthermore, it overlaps with a very old philosophical tradition different from the systemic one: the so called "process philosophy".

We have introduced briefly that tradition. Also, we have analyzed the tension between the systemic thought and the processual thought in SD, identifying the different contexts in which the tension appears. Finally, we have show how a process perspective can offer advantages in relation to a number of very important issues: 1) the ways of understand difficulties in forecasting, 2) the ontological consequences of the claim that there are levels of reality, 3) the selection of the degree of generality/specificity in description and explanation, 4) the selection of the degree of generality/specificity with respect to normative and evaluative questions, and 5) the problem of realism concerning the structures postulates in the models.

To take into account the conceptual relationships of SD with the tradition of process philosophy would be very important in order to achieve a better reflective understanding

of the connections between structure and behavior, which would benefit both to practitioners and to theoreticians of SD.

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