The Role of Process Ontology in Cybernetics

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Abstract
The purpose of this paper is to show the role of process ontology in cybernetics. The philosophical foundations of cybernetics were laid by Norbert Wiener, who used a language full of human-machine metaphors described in terms of information, feedback, and control. We will show that various fields of science still use essentially cybernetic definitions today, which will lead us to a reformulation of such a language from a philosophical point of view: The goal of cybernetics is the study of process analogies. Using the principle of compositionality, we will show how a cyberneticist can easily argue for the ontological sameness of two processes. Such a framework could lead to cybernetics being seen as a fully grounded philosophical theory. As a corollary, we point out that there is a growing need for cybernetics because, thanks to its specific process ontology, it provides a theoretical framework that ontologically bridges dualisms that occur throughout contemporary science.

Keywords
cybernetics, process ontology, analogy, principle of compositionality, dualism

Philosophy in Cybernetics[1]

The philosophical foundations of cybernetics were laid in 1948 with Norbert Wiener's book *Cybernetics, or Control and Communication in the Animal and the Machine* (Wiener 1961, originally 1948). What Gerovitch would later call *cyberspeak* was originally conceived as a new universal language associated with a variety of human-machine metaphors, described in terms of information, feedback, and control (Gerovitch 2002, 53). This put cybernetics on a collision course with Marxism (of the Soviet neo-Soviet period) and later to its blind incorporation into every aspect of Soviet life, which in a sense did little to change the underlying metaphysical assumptions and merely demarcated cybernetics as a new ideology. To illustrate, at the 1958 philosophical conference, Lyapunov and Sobolev were accused of reducing the concept of life to the circulation of information, and such transmission was considered illegitimate (Gerovitch 2002, 215), to which Sobolev replied that if heredity was not described as the transmission of information, the only alternative would be to appeal to divine providence. The crux of their discussion can be compared to today's scientific definitions. For example, the definition of life from NASA (Benner 2010) states that life is a "self-sustaining chemical system capable of Darwinian evolution". Such a definition, which so intuitively

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The authors would like to thank the anonymous referees whose valuable suggestions were instrumental in formulating the final version of this paper. In particular, we would like to thank one of the referees for a number of motivating and valuable suggestions. The final sentence in the abstract is a paraphrase of his/hers comment to our paper, and we consider it a remarkable and clear summarisation of our ideas presented in this paper.

passes for a cybernetic definition, is repeatedly attacked with various examples from the biological world that are not considered living beings but are covered by this definition, such as a sodium chlorate crystal that can reproduce and whose properties can be passed on to its descendants (Benner 2010).

Nowadays, philosophers unwittingly use cybernetic definitions as their preferred method of defining and distinguishing metaphysical and epistemological objects. This is an almost scandalous non-recognition of cybernetics, made worse by the fact that cybernetics was developed by a philosopher, Norbert Wiener (discussed in Dupuy 2000, ch. 2). As an example of this deliberate avoidance of cybernetics, Hartmann offered his definition of a simulation, stating that "a simulation imitates one process by another process" (Hartmann 1996). Durán states that

"… Hartmann's definition stands on three statements:

a) a simulation is a result of solving the equations of a dynamic model

b) a computer simulation is a result of having a simulation running on a physical computer

c) a simulation imitates another process." (Durán 2020, 304)

This inherently cybernetic definition attempts to connect a mathematical model to a physical computer by simply talking about processes. When a) is complemented by b), a computer simulation results from implementing a dynamic mathematical model on a physical computer. Even if we consider Durán's analysis valid, Hartmann's definition seems plagued by other metaphysical problems. This gives rise to the need for a "process ontology" since *process* is an essential part of integrating cybernetics not into language as a new ideology but into the underlying metaphysical worldview. In this paper, we will show that "process ontology" is a non-trivial extension for any metaphysical system since the ontology of processes has important self-referential aspects.

But is this pure philosophy with inadvertent cyberspeak, or is there cybernetics in philosophy? To understand the intuition behind such questions, one should note that Hartmann's definition speaks of processes without ever addressing the metaphysical nature of a process. The strength of Hartmann's definition is that it makes no distinction between physical processes or, say, multiply generated computer programs, and can be applied either to a mirror image of the physical world or to a computer simulation. This was only possible because he used cybernetics as a background theory, allowing him to easily switch between different domains. To understand this, one should recall that Wiener introduced cybernetics as a methodological approach in the introduction to his 1948 book (Wiener 1961). There it is argued that the task of cybernetics was to explore the analogies between processes in animals and computers and to explore their philosophical ramifications (Wiener 1961, XV).[2]

It could be argued that, unlike the Soviet sphere of influence explored in more detail by Gerovitch (2002), Western societies were culturally predisposed to be highly receptive to the implications of Wiener's ideas, which were already being culturally absorbed by science fiction and technologically implemented once the technological conditions were met. Although there is no direct citation to support this claim, it requires careful consideration, which is best achieved by comparing it to the many obstacles to the cultural integration of cybernetics on the other side of the Iron Curtain. The Eastern Bloc had largely adopted Marxism as a state ideology, and the main problem was the social position of the computer. Since man constructs history, the computer is at best a tool. But in the beginning (Matyerialist [Материалист] 1953) the argument was quite different. Computers were considered tools, but it was argued that cybernetics sought to elevate these tools to the role that Marxism had reserved for man, namely the creation of history. Moreover, a tool with a high degree of autonomy would reduce the need for skills to operate it, and as such would make its operators (the proletariat) redundant over time. The question "Who does cybernetics serve?" was thus answered ideologically, making cybernetics a theory that was metaphysically incompatible with Marxism. Cybernetics was presented as contradictory to Marxism, a thoroughly philosophical theory, which in turn meant that cybernetics was also (badly) presented as a philosophical theory. It took the work of Lyapunov, Kitov and Sobolev (Sóbolev, Kitóv, Lyapunóv 1955) to reformulate cybernetics as a complete and well-developed philosophical theory, and only then to show that it was fully compatible with Marxism. But process ontology, the metaphysical heart of cybernetics that makes cybernetics primarily a philosophical theory, remained undiscovered.

Cybernetics in Philosophy

As Wiener pointed in (Wiener 1961, xi–xvi and 11–13), the main objective of cybernetics as a science is to study the analogies between humans and machines, but the original goal of cybernetics could be rephrased as follows: *The main objective of cybernetics as a theory is to study process analogies*. The most important question now is whether cybernetics is reductive,[3] that is, whether analogous processes are to be regarded as the same process? Is the equivalence of *mind – machine* more important than the differences in substrata? This question is difficult to answer as such, since it depends largely on metaphysical preferences. We want to show that by examining process ontology, one can indeed provide a fully grounded metaphysical basis for cybernetics that fully equates two analogous processes over different substrates, as a consequence of a fully neutral process ontology, i.e., appealing to some metaphysical properties of processes that seem quite rational.

A simple example of process ontology working in the background of cybernetics would be to equate Boolean circuits[4] with mathematical reasoning on the one hand and formulae of propositional logic on the other. They all describe (perfectly) "analogous" processes, over different metaphysical substrates. In this example, there is virtually no difference in viewpoint: Both the cybernetic and the "classical" views agree, and both regard the abstract process of model checking as exactly the same thing. One reason for this might be that both propositional logic and Boolean circuits were developed specifically

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It is interesting to note that Wiener was a philosopher in the formal sense: he had a Ph.D. in logic from Harvard University, and both of his thesis supervisors, Karl Schmidt and Josiah Royce, were philosophers. Schmidt's dissertation was titled *Beiträge zur Entwicklung der Kant'schen Ethik*, while Royce's was *Interdependence of the Principles of Human Knowledge*. These facts can be verified at https://www.genealogy.math.ndsu.nodak.edu/index.php (accessed on 15 November 2021).

3
We would like to emphasise here that the question of whether a theory is reductive is almost exclusively used to evaluate philosophical theories.

4
For more information on circuits, see e.g. (Jukna 2012) which provides an excellent overview.

for mathematical reasoning. However, we will show that this equation is the consequence of a fairly rational process ontology, and this is what makes cybernetics beautiful as a philosophical theory: the equating is not a reduction, but a natural consequence of a simple process ontology.

The preceding example illustrates a simple case. In a sense, more complex cases will not differ significantly from this case, since all human-made theories and technologies are in some sense copied from nature. If the correspondence is to be relaxed in terms of precision, we would not claim that we are "the same" as nature, but merely that our theory or technology is "inspired by nature." Theological and Cartesian ramifications aside, this means that all human creations (or discoveries, if one prefers the realist usage) correspond to at least some natural phenomena. Although one might be tempted to find counter-examples of artefacts that are in no way inspired by nature, this is irrelevant to our point – it may extend it, and as such provides a direction for future research, but does not contradict it. The view that there are analogies between human-made artefacts, be they theories or technologies, is almost universally accepted as plausible. But if this is so universal, what is so special about cybernetics? In a word, cybernetics has hitherto been regarded as a reductionist theory, but we will show that it discards nothing – its methodology follows entirely from process ontology in a very straightforward sense.

Cybernetics Riding Shotgun: the "Solution" of the Mind-Body Problem in Early Artificial Intelligence Research

As reported by (Crevier 1993), Herbert Simon said in 1956 that he and Newell invented a thinking machine (the Logic Theorist, the first AI program in history). In particular, he noted that by doing so they have *solved* the mind-body problem. A crucial question here is: Why can Simon claim to have solved the mind-body problem if the processes are just analogs? There seems to be a natural answer here. Simon thought that their solution was to show that (some) cognitive faculties are not inherently human and cannot be achieved by a machine. This can be understood as a rejection of strong faculty dualism. But this understanding is flawed. If it is enough to show that there is a cognitive ability that can be implemented on computers, why did we need a symbolic process? Why were the basic operations relating to the various substrates not considered sufficient? As noted by Ashby (and reported in Pickering 2010, 25–31), *without cybernetics as an underlying ontology and methodology, no claim of the ontological sameness of the process in the human and machine could have been made*. It is only by embracing cybernetics as metaphysics that they might even begin to argue for a non-dualist view, which clearly demonstrates the epistemological power of cybernetics.

Regarding dualism, most modern philosophy of mind is concerned not with fundamental reductions but with cybernetic process equality. For example, mind-brain identity theory, a form of physicalism, holds that mental states *are identical* to states and processes of the brain (Smart 2017, sect. 5). Such an identity presupposes not a reductionist principle but a cybernetic principle, which holds that mental processes are ontologically the same as internal brain processes. Scheutz (Scheutz 2001, 543–544) argues that we usually think of a functional correspondence between physical states and computational states when we try to explain what it means to implement a computation for a physical system.

If we are to take the word of Rescorla (Rescorla 2020) as representative of the computationalist camp, the computationalist theory of mind claims that the mind is a computational system and its problem solving are computations similar in important respects to computations executed by a Turing machine. Their arguments implicitly presuppose a cybernetic methodology and ontology. Otherwise, it would be difficult to explain the greater or lesser correspondence of processes on different substrates.[5] In a sense, the cybernetic view here is a simple one, as presented by Ross Ashby at the Macy conferences (Malapi-Nelson 2017, ch. 6) and in the introduction of his book (Ashby 2015, 5): machines need not be mechanical. A machine is an information-modifying process, and from the point of view of cybernetics, the substrate is irrelevant. One could argue that, from this viewpoint, most modern, inherently dualistic AI uses pleonasms such as "machine learning".

Process Ontology

The goal here is to provide the main argument on how a cybernetician might reconstitute any symbolic process so that any two processes that are analogous, are actually the same process.

In essence, we want to show that the statement

"I have two different substrates which in analogous *ways* realize the same process."

directly follows from the more moderate statement

"I have two different substrates which in the same *way* realize two analogous processes."

At this point, it should be noted that the *way* referred to in these statements *is actually a process*. By using a version of Plato's third-man argument (Plato, 2019), let us formulate our argument.

We need an additional assumption, which we call the *principle of compositionality of processes*:

Any process that can be described (with conjuctions and disjunctions) as having subprocesses $p_1, \ldots, p_n$ *can be functionally restated as a composition (serial or parallel) of processes* $p_1, \ldots, p_n$.

The principle of compositionality of processes might seem to require evidence, if not even a "proof", but we find it quite natural. If a process (with a fixed input/output pairing) can be described with subprocesses that in turn can be (re)composed to form a process with the same input/output pairing as the original process, the composition *is ontologically the same* process as the

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There is an interesting digression that can be addressed here, and we thank one of the referees for bringing it to our attention. From a historical perspective, the Symbolists of the 1950s and 1960s were the disciples of the original cyberneticists and competed for the same funding. Unlike their mentors, they had some results that contributed to higher funding, which in turn contributed to the decline of classical cybernetics. They had more success because symbolic computation was easier for the computers of the time and they could produce results. Their success (measured mainly by the technology produced) contributed significantly to the rise of the computational theory of mind. But the main idea is flawed because computational theory of mind essentially takes the intentional simplifications of symbolic computation at face value and assumes that it can produce AI-like results because it better describes reality (a realist view), while completely neglecting the fact that the main reason it produces results is because it is orders of magnitude simpler and therefore implementable (instrumentalist view).

original process, *qua* process. A sceptic argument against it might go along the lines of the "kripkenstein" argument (Kripke 1982, 8–21), but here we put the emphasis on the input/output pairing of the *whole* process, not just of an extension of an initial segment. Since any sufficient description (in any language) is an algorithm, it defines subprocesses as algorithms, which are themselves processes. Such subprocesses may, of course, be constructed serially one after the other, which corresponds (more or less) to conjunction of descriptions, or in parallel, which corresponds (more or less) to disjunction.

Our argument is as follows. Suppose we have analogical processes P and Q over two different substrates, S_1 and S_2. What we mean by analogical is "symbolically the same, yet different in other aspects". Think of addition in the mind and in the computer. Analogical processes P and Q then are connected by the same symbolic content, let us call it Y. So in essence we have $P \cap Q = Y$ and $S_1 \cap S_2 = 0$. But here we are talking about processes, not real sets, but by using the principle of compositionality, we can almost do set operations. In fact, by the principle of compositionality, Y can be removed from the processes P and Q, and set as a different process which comes after P\Y or Q\Y did their magic. We can call P\Y simply P_1, Q\Y we denote as Q_2 and the now "independent" Y as Y_1. It is clear that Y_1 is a purely symbolic process, and that S_1 and S_2 are purely substrates.

P_1 and Q_1 are responsible for Y_1 connection to S_1 and S_2, and they might still have a lot of subprocesses in them. Some of them are purely "adhesive", i.e. they connect Y_1 to the substrates, and some of them might be symbolic, i.e. some processes that are needed between the adhesive parts and Y_1 as the ultimate symbolic process. Since the substrates are different, the adhesive parts of P_1 and Q_1 are different, but since Y_1 is the same for both P_1 and Q_1, it means that there is a symbolic subprocess that P_1 and Q_1 have in common. By using the principle of compositionality again on P_1 and Q_1, we can remove an additional symbolic part, Y_2 from P_1 and Q_1 and obtain P_2 and Q_2 which are void of Y_2.

Now the final symbolic process Y_1 is preceded by another symbolic process Y_2, and Y_2 is connected by P_2 to S_1 and by Q_2 to S_2. If P_2 and Q_2 are purely adhesive, we stop, if not we reiterate the process until they are. The final result is that all symbolic processes have been reconstituted to be the same process over different substrates, and the only parts of the (now single) process which is different are the substrates and the last P_n and Q_n which are purely adhesive, i.e. contain nothing symbolic, only a simple connector to the different substrates.

Conclusion

What we have shown with our argument is that all processes that are analogical can be redescribed as being the same up to the point where the only difference is the non-symbolic last layer which acts as an adhesive of the symbolic chain of processes to the different substrates. This argument depends on the principle of compositionality of processes, which is in itself not problematic. It also depends on the nature of the processes involved. One could say that our argument will work well for arithmetical processes, but what about e.g. "seeing a cat"? Although this seems like an important objection, in fact, it is not. Any process which contains a symbolic part is subject to our argument since the symbolic part is the one to be abstracted. Seeing a cat has a symbolic part, and that part can be abstracted: both a human and a machine tag a photograph as "Cat", and that is a purely symbolic process. Also, the human and the machine are different substrates. What our argument says is that apart from the final symbolic process and the substrates, we can divide all intermediate steps into symbolic and adhesive parts, by removing one symbolic part at the time until all we have is adhesive processes. Then, the different adhesive processes have no symbolic part in them, just the connectors to the different substrates.

In the larger context of cybernetics, our argument shows that cybernetics is not only a technical science but a highly philosophical one, i.e. cybernetics is a non-dualist metaphysical theory. The philosophical aspect of cybernetics is not a manifest one, not even an eliminativist one. It is a purely rational position that at its core sits upon a peculiar ontology of processes, which behave in the way we have described. As such, cybernetics is not an intellectual shortcut, but a fully grounded philosophical approach that emphasizes processes over objects, as almost every traditional theory does. If traditional philosophy is object-oriented, then cybernetics does the same thing, but it is process-oriented. One then might be tempted to call cybernetics simply "procedural philosophy".

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Sandro Skansi, Kristina Šekrst

Uloga procesne ontologije u kibernetici

Sažetak

Svrha je ovoga rada pokazati ulogu procesne ontologije u kibernetici. Filozofske temelje kibernetike postavio je Norbert Wiener, koji se služio jezikom punim metafora čovjeka-stroja, opisanih u terminima informacija, povratnih informacija i kontrole. Pokazat ćemo da se različita područja znanosti i danas koriste bitno kibernetičkim definicijama, što će nas dovesti do preformulacije takvog jezika s filozofijske točke gledišta: cilj je kibernetike proučavanje procesnih analogija. Koristeći se načelom kompozicije, pokazat ćemo kako kibernetičar može lako argumentirati ontološku istost dvaju procesa. Takav okvir mogao bi dovesti do toga da se kibernetika smatra potpuno utemeljenom filozofijskom teorijom. Kao posljedicu, ističemo da postoji rastuća potreba za kibernetikom jer, zahvaljujući svojoj specifičnoj procesnoj ontologiji, ona pruža teorijski okvir koji ontološki premošćuje dualizme prisutne u cijeloj suvremenoj znanosti.

Ključne riječi

kibernetika, procesna ontologija, analogija, princip kompozicionalnosti, dualizam

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Die Rolle der Prozessontologie in der Kybernetik

Zusammenfassung

Die Intention dieser Arbeit ist es, die Rolle der Prozessontologie in der Kybernetik aufzuzeigen. Der philosophische Unterbau der Kybernetik wurde von Norbert Wiener geschaffen, der eine Sprache voller Mensch-Maschine-Metaphern verwendete, die unter dem Aspekt von Information, Feedback und Kontrolle geschildert wurden. Wir werden zeigen, dass differente Wissenschaftsgebiete auch heutzutage noch im Grunde kybernetische Definitionen verwenden, was uns zu einer Neuformulierung einer solchen Sprache aus philosophischem Blickwinkel führen wird: Das Ziel der Kybernetik ist die Erforschung von Prozessanalogien. Anhand des Kompositionalitätsprinzips werden wir darlegen, wie ein Kybernetiker leicht für die ontologische Selbigkeit zweier Prozesse eintreten kann. Ein solcher Rahmen könnte dazu führen, dass die Kybernetik als eine vollständig begründete philosophische Theorie erachtet wird. Als Schlussfolgerung deuten wir darauf hin, dass ein wachsender Bedarf an Kybernetik besteht, da sie dank ihrer spezifischen Prozessontologie einen theoretischen Rahmen liefert, der die in der gesamten zeitgenössischen Wissenschaft in Erscheinung tretenden Dualismen ontologisch überbrückt.

Schlüsselwörter

Kybernetik, Prozessontologie, Analogie, Kompositionalitätsprinzip, Dualismus

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Le rôle de l'ontologie processuelle dans la cybernétique

Résumé

L'objectif de ce travail est de montrer le rôle de l'ontologie processuelle dans la cybernétique. Les fondements cybernétiques ont été institués par Nobert Wiener qui se servait d'un langage rempli de métaphores sur l'homme-machine, décrites en termes d'informations, de retours d'informations et de contrôles. Nous montrerons que les divers domaines de la science utilisent aujourd'hui encore des définitions cybernétiques, ce qui nous amènera à reformuler un tel langage à partir du point de vue philosophique. Le but de la cybernétique est d'enseigner les analogies processuelles. En nous servant du principe de composition, nous montrerons comment le cybernéticien peut aisément argumenter en faveur de l'identité ontologique de deux processus. Un tel contexte pourrait mener à l'idée selon laquelle la cybernétique trouverait entièrement ses fondements dans la théorie philosophique. En conséquence, nous mettrons en avant le fait qu'il existe un besoin grandissant pour la cybernétique puisque, grâce à son ontologie processuelle spécifique, elle offre un cadre théorique qui ontologiquement dépasse les dualismes présents dans la science contemporaine.

Mots-clés

cybernétique, ontologie processuelle, analogie, principe de compositionnalité, dualisme