space as set theoretic statements and logical formulas.

« 13 » Still, being a part of the spatio-temporal continuum is not equivalent to having a "body," one could reply, perhaps leveraging the philosophical definitions of a living body offered (among others) by Maurice Merleau-Ponty or by Hans Jonas. Lizards and humans have bodies. Plants and bacteria may have them. Rocks certainly do not. The objection carries a certain weight, but its import about the status of "computers" is less conclusive than it may seem. What if we could give computers a body? What if we could allow computers to interact autonomously with the world on the basis of their internal needs? Would those computers still be suffering from the symbol grounding problem? My question is rhetorical, of course: embodied computers are called robots. That we still do not know how to build fully autonomous robots is not important. As long as we do not have conclusive evidence that such creatures cannot be built, the assertion that "computers suffers from the symbol grounding problem," cannot, in my opinion, be taken as true.

« 14 » Moreover, the same epistemological issue about computers being (models of) a cognitive agent I mentioned above reappears. One could grant that (future) autonomous embodied robots may be self-referential, end-oriented beings and still deny that ordinary devices such as the desktop computer with which I am writing this paper will ever be one. Even if this last statement were unconditionally true, it would still be the case that I can use a disembodied, non self-referential, non-end-directed desktop to *simulate* (i.e., to *model*) certain aspects of autonomous robots' behavior. In fact, this is precisely how a large part of everyday work in robotics is routinely carried out (including *all* the work in evolutionary robotics). In my view, the symbol grounding problem tells us a good deal about cognitivism, but very little about "computers."

« 15 » Let me conclude. Füllsack's argument about the alleged incompatibility between computers and constructivism depends on some questionable assumptions that cannot sustain scrutiny. We can only find an incompatibility if we substantially narrow the meaning of "computers" to designate, for instance, abstract Turing machines or cognitivist symbol systems. Under those readings, though, the argument's conclusion turns out to be trivially true.

« 16 » Yet my critique does not touch the substance of Füllsack's work, only its logical presentation. Determining if "computers" are incompatible or not with constructivism's insights is not important. A constructivist would rather claim that what is important is to use them to further our understanding of ourselves. In this respect, I think Füllsack's work succeeds. The computer simulations he discusses shed light, as he claims, on several questions about the "constituencies of life, the functioning of cognition and the emergence of mentality" (§2). His claim would only be strengthened by removing its dubious link to computers' "unconstructivist" nature.

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Received: 12 October 2013
Accepted: 18 October 2013

Weak and Strong Constructivist Foundations

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> Upshot • Füllsack's article offers many interesting ideas but falls short of elucidating the relationship between constructivism and computation. It could profit by taking into consideration stronger constructivist foundations such as the distinction between machine and organism, the relationship between reality and the observer, and Ceccato's theory of attention.

"it is the coherence of experiences with other experiences that constitutes the foundation of all explanation"
Humberto Maturana
in Maturana & Poerksen (2004: 42)

« 1 » Manfred Füllsack introduces and outlines some interesting and useful ideas. For example in §18, the Bayesian brain approach of contemporary robotics is said to confirm Piaget's consideration of sensorimotor interaction as being circular and recursive; further, in §32, Mark Bedau's definition of "emergence" in terms of computer-based simulation according to which emergent properties are not reducible other than by way of computation is outlined. There is also the simulation of "downward causation," with Joshua Epstein's *demographic prisoner's dilemma* (§39ff.), which merits further attention. This is especially so where the author discusses a "cooperation model" that explains aspects of the "coevolution of system and environment," for example "emergence" and "immergence." However, Füllsack's claim that "constructivism and computation do not contradict" (§55) does not appear to be sufficiently justified. Could this be due to the weak constructivist foundations on which the paper is based? For this reason, my comments will focus on an attempt at strengthening these foundations by pointing at three essential issues: a distinction between machine and organism, the relationship between reality and the observer and Silvio Ceccato's theory of attention.

Machine vs. organism

« 2 » In §8, the author claims that a "close connection" between constructivism and computer-based modelling becomes clear when simulation illustrates how "realities sui generis (a.k.a. systems) can emerge." In my view, this illustration is useful but not relevant nor essential since a sophisticated machine could do the same. What we need instead is a convincing, viable distinction between an organism (living organisation) and a machine (dead organisation). A good source of inspiration for such a distinction was provided more than 200 years ago by Immanuel Kant (1981), who discusses the issue in detail and finally suggests that "An organized natural product is one in which

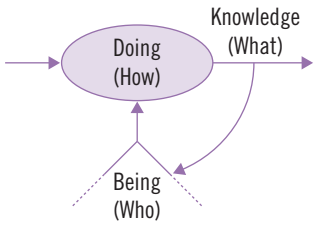

Figure 1: Autopoietic knowledge model (after Bettoni 2005: 23)

everything is an end and reciprocally also a means" (A292, my translation[3]). Obviously, this is not the case in a machine, since, as Kant himself suggests in one of his rare examples:[4]

> "In a watch one part is the instrument that moves the other parts, but a wheel is not the efficient cause of the generation of the other; a part is present for the sake of another, but is not generated by the other." (A288, my translation[5]).

« 3 » In Kant's distinction between machine and organism, I see a prelude to Humberto Maturana & Francisco Varela's concept of autopoiesis[6] (Maturana & Varela 1980: 79). It was this concept that in the following years enabled Maturana to provide further developments (such as the criterion of validation of scientific explanations, the distinction of two explanatory paths of objectivity, the operations of distinction of the social and of the ethical, etc.) concerning the relation between reality and the observer (see next). In my view, they constitute some of the most essential, strong foundations of constructivism.

« 4 » In an earlier work of mine, for instance, where I characterized the cognitive system as an organic system, I was inspired by autopoiesis to specify it further as follows (Bettoni 2005: 18; Bettoni & Eggs 2010: 134). What we construct in the act of knowing (doing) can be fed back to the cognitive functions, and this feedback is such that the knowledge fed back becomes a *component* of the cognitive functions that produced it: thus knowledge is not just a result! Thanks to the feedback, the new construct becomes an integrated system element and builds on, extends, enhances the potential, the cognitive means, the being of a person. In the language of cybernetics, we would talk of the operation (doing), operand (knowledge) and operator (being); the special thing here is that the fed-back operand *becomes a function* that expands the mechanism from which it originated. And so the whole system grows (dotted lines in Figure 1), i.e., when the system is active, it also grows in its capabilities. Doing generates being: this is how I interpret "autopoietic."

Maturana about reality and the observer

« 5 » In a well-known article dating from 1988, Maturana states that "the most central question that humanity faces today is the question of reality" (Maturana 1988: 25). However this does not appear to be the concern of the target article, which instead focuses throughout the text on circularity, and at the end (§55), characterizes the constructivist conception of knowledge as "circular"; but if circularity is so important, what is its relation to the question of reality?

« 6 » In the end, realism is not expressively refuted (§55), leaving the choice between realism and constructivism "a matter of taste." This is an attitude that shines through the whole text but in my view prevents the authors from making progress in solving the problem of reality in a more viable way. In the constructivist thesis that "reality is the construction of an observer" and in the realist thesis that "reality exists independently" (§4), the term "reality" is merely a homonym that means two different things; hence it is confusing to mention them as if they would mean the same thing. For me as a constructivist, the reality that I construct is not a physical reality but a conceptual one. For a realist, on the contrary, the reality that he sees as existing independently is actually a combination of the two: physical reality as the "reference" and conceptual reality as its "copy" in his head. In constructivism, we need to disentangle these two things, and here is where Maturana's reflections about autopoiesis and cognition become essential. Consider, for example, his differentiation between two fundamental ways in which we, as humans, can understand explanations; he distinguishes two mutually exclusive explanatory paths: the path of "objectivity without parentheses" and the path of "objectivity with parentheses" (Maturana 1988: 28ff).

« 7 » On the explanatory path of objectivity without parentheses, the observer assumes either implicitly or explicitly that he is capable of making statements about the logic of things, as if the logic he accords to them would exist independently of him. He does not ask himself: "How can I say that the logic of this thing exists independently of me?" If someone makes the implicit assumption that he can reference things, as if the logic he accords to them exists independently of him, then he is also effectively stating that the explanations he applies can ultimately be validated by the things themselves, independently of him. This explanatory path therefore contains the implicit and unaware assumption that an individual can reference a logic that exists independently of him and that validates what he says. And what could that be? It is a logic of reality (the logic of being, the essence of things, etc.) or, in other words, a universal truth. It is universal because it exists independently of us. It is valid for everything because it is independent from everything.

« 8 » On the explanatory path of objectivity with parentheses, the observer notes something different, something very interesting: that his explanations are validated by his actions. The logic of his experience is explained by the logic of his other experiences and not by a reference to a logic that is independent of us. The observer sees himself as a source of validation for his own statements. This is the essence of the essence of constructivism! According to Maturana, the

3| Original: "Ein organisiertes Produkt der Natur ist das, in welchem alles Zweck und wechselseitig auch Mittel ist."

4| Jakob von Uexküll discussed the general distinction and the specific case of the watch in more detail. See, e.g., Ziemke (2012)

5| Original: "In einer Uhr ist ein Teil das Werkzeug der Bewegung der andern, aber nicht ein Rad die wirkende Ursache der Hervorbringung des andern; ein Teil ist zwar um des andern Willen, aber nicht durch denselben da."

6| The fact that in their definition Maturana and Varela speak of an "autopoietic machine" is not relevant, since their term "machine" here is more an awkward way of avoiding animism (Maturana & Varela: 76) than a well-conceived category for things like Kant's watch.

parentheses around "objectivity" represent awareness – that special awareness that we, in order to validate our explanations, are unable to refer to or reference anything (neither a thing nor a logic) that is independent of us. Plus an awareness of the fact that our explanations are validated by coherence in the logic of our experiences: "In fact, scientific explanations do not explain an independent world, they explain the experience of the observer" (Maturana 1988: 38).

« 9 » By being aware that we explain the logic of our experience through the logic of our experiences, we notice that there are numerous domains of explanation because each domain of coherent experiences represents a domain of explanation: in this domain, we can draw on experiences within it in order to explain other experiences from it. And since each of these domains of explanation is experienced as a domain of objects or as an area of reality, this explanatory path gives rise to numerous realities, even if the physical reality remains one. This is because they are "realities for me" and not absolute realities. But how could we make this step and reach the awareness mentioned by Maturana?

Ceccato's "Theory of Attention"

« 10 » Something that could help us become more aware of our construction of reality is, for example, Ceccato's "Theory of Attention,"[7] inspired by Percy Bridgman's operationalism.[8] His "operational idea" was the starting point for a development in theory that led to approaching concepts as operations (operational analysis of concepts), one of the core thoughts behind radical constructivism. Physicist Bridgman discovered that the problem of simultaneity in Einstein's theory of relativity can be elegantly resolved by defining the concept of simultaneity by means of operations. This approach from physics also fitted perfectly with Ceccato's idea that we construct concepts through mental operations (Ceccato 1947): Ceccato started to devise an analysis of concepts that could identify the mental operations needed to generate a concept.

« 11 » According to Ceccato's theory, the actual fundamental conceptual operations are not physical actions, as in physics, but rather "moments" or "states" of attention. Attention is usually presented in psychology or common sense as a kind of spotlight that illuminates something. In the case of Ceccato, attention is a much more comprehensive function (an attentional system or organ), which has a special "constitutive" and also "regulative" impact rather than being purely image-based: the operations of attention determine the object as far as its logic is concerned, and not the other way around. Attention is the mechanism by means of which we create our constructs, our reality; the *How* (attentional operations) determines the *What* (our reality), as far as its logic is concerned.

« 12 » The functionality of this proposed attention organ, which I call the "categoriser," is derived from a pulsating fundamental notion: the categoriser produces an uninterrupted and even rhythm of ("conscious") moments or states, rather like our breathing and circulation. Experiments in neuroscience have indirectly confirmed this approach on several occasions (Harter 1967; Lehmann et al. 1998). Dietrich Lehmann and his research group in Zürich, for example, have devised experimental results that suggest that "the seemingly continuous stream of consciousness consists of separable building blocks." These attentional blocks or moments serve as building blocks in the construction of more complex units (Bettoni 1989: 13). Through mental operations (so-called "categorising"), we construct these units using the categoriser, combining the moments with one another (free moments) and with the functioning of other organs, e.g., sensory impulses i.e., the eyes, ears, etc. (focalised moments). Ceccato gave the name of "mental categories" to these connections between free moments of attention, in honour of Kant (Ceccato & Zonta 1980: 53). Examples include pure terms such as "something," "object," "and," "or," "with," "singular," "start," "end," "element," "point," "true" and "energy," etc. Examples of connections from focalised moments are "hard," "water," "horse," "melon," "paper," "pencil," "cat," "guitar" and "sun," etc.

« 13 » In §28 Füllsack mentions the focus of European epistemology on substances and objects rather than on "processes that bring them about." This seems to be a good place to link with Ceccato's theory of attentional operations; but the focus must be on a *functional* level, not on the recursive processes mentioned in the article, because these belong merely to the *implementation* level.

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Received: 12 October 2013
Accepted: 21 October 2013

The Construction of the Environment

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> Upshot • The environment is not slowly constructed by the agent but is an integral part of being an agent because both, agent and environment, are part of a closed loop system. By identifying the perturbations impacting on the loops, with the help of second-order cybernetics, the agent can identify them as its environment.

« 1 » My main criticism of this article is the establishment of the environment (see §§ 24 and 25). In the classical constructivist tradition there is, of course, no "real" environment and it needs to be constructed. Through the interaction with "something," we construct the environment. In my initial review, I dared to say "real environment" and the author rightfully reminded me of the dispensable nature of the "real world" in constructivism. I am now going to describe

7| A brief description of this theory can be found in Foerster & Glasersfeld (1999: 49ff).

8| Heinz von Foerster, Ernst von Glasersfeld and Ceccato explicitly considered Bridgman to be a sort of "enlightenment" (Foerster & Glasersfeld 1999: 45).