Diving Deeply into Radical Constructivism

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> **Upshot** • Applying radical constructivism to machine learning is a challenge that requires us to dive very deeply into its theory of knowing and learning. We need to clarify its fundamental concepts, if possible, in operational terms. This commentary aims at outlining how this kind of clarification could look in the case of 3 such concepts: (a) the construction of experiential reality; (b) learning as a constructive activity; (c) the viability of conceptual structures.

Introduction

« 1 » One of the major experiences that led Ernst von Glasersfeld to adopt a constructivist way of thinking was his pioneering work in artificial intelligence, starting in 1959 with the machine translation project at the Centre for Cybernetics at the University of Milan, created and directed by Silvio Ceccato (Glasersfeld 1995: 7). Thus, I am rather enthusiastic about the idea of applying von Glasersfeld's theory of knowing and learning to machine learning (ML) and hope that my comments will support the efforts of Markus Nowak, Claudio Castellini and Carlo Massironi in continuing this promising line of research.

« 2 » In the field of assistive robotics for limb amputees, electromyographic signals generated by muscle activity in the remaining upper limb are used as input data for a machine learning (ML) system; the system should then produce control commands for a prosthetic arm/hand accordingly in order to let it perform the desired action (§33).

« 3 » Unfortunately, this so-called upper-limb myocontrol, after 40 years of research, is still failing (§34) with rejection rates of up to 75%. As a means of improving such systems (smart prosthetic arm/hand control systems), the authors of the target article suggest (§32) developing traditional ML to form an *interactive* machine learning (iML), which allows for system updates whenever its actions are unsatisfactory (§§21f). But this poses new problems, which require appropriate conceptual tools, in particular, a coherent conceptual framework about interactivity. This is where the authors anticipate that radical constructivism (RC) could help (§23), especially through its concepts of experiential reality (§15), learning as a constructive activity (§16), viability (§17), assimilation, scheme theory, accommodation and equilibration (§30).

« 4 » The application of RC to iML – so called *RC-framed iML* – for the task of upper-limb prosthesis is expected to provide useful insight into how to design the interactive prosthesis of the future (§89). The authors are convinced that their approach has the potential to improve human-robot interaction. Thus, they propose to shift the attitude towards ML from a realist to a radical constructivist attitude, as defined by von Glasersfeld (§13). They see their draft of an RC-framed iML presented in the target article, as an attempt at opening a discussion between the RC community and the ML community (§26).

« 5 » Applying RC to ML requires us to dive very deeply into radical constructivism and clarify its fundamental concepts. So, I will look at three fundamental concepts used in what the target article calls a "tentative framework" (§26) about "interactivity" (§23) and will try to dive deeper into them.

A | The construction of experiential reality

« 6 » Nowak et al. mention this concept and quote von Glasersfeld (1995: 58f) as a reference where it appears as a section title. I will highlight the essential parts of this section by not only repeating the same formulation but also by reformulating and extending them in my own terms.

« 7 » Humans, as infants and later as adults, can construct the reality they experience for themselves. As infants, humans develop the basic concepts that constitute the essential structure of their individual experiential reality, without needing a specific physical structure to exist in its own right as a *corresponding* structure.

« 8 » For example, let us look at the development of the notion of the "object" in a human infant. In phase 1, the infant coordinates sensory signals recurrently available at the same time in its sensory field (the "locus" of raw material that Immanuel Kant called "the manifold") and establishes by that many different object concepts; these object concepts are like operational routines for constructing the formerly constructed objects of interest again at a later point (a ball, a face, a cat, etc.) whenever suitable sensory components are available. The notion of "object" in general, then, is whatever the mind constructs *as common* to all these routines (a kind of abstract, generalised, operational routine) due to a principle of efficiency, implemented like in perception by means of "preferred paths" or "sequence patterns" (de Bono 1991: 81f; de Bono 1992: 10f). Later, in phase 2, the infant becomes able to run through such operational routines even when no suitable sensory components are available in its sensory field; in this case, the infant executes a conceptual coordination of a previously constructed object; it produces a *re-presentation* (written with the hyphen as a reminder that this term means a repetition, a replay, a re-construction from memory, of a past experience, not a picture of something in a mind-independent world).

« 9 » Thus, I do not agree with Nowak et al. when they say that the agent tries to "*organize perceptual objects*" (§15). Rather, I would avoid both "perceptual" and "objects" and say that the agent "organises a sensory field," conceived as the raw material that Kant called “the manifold,” in which there are no objects unless we construct them. And when we have constructed them, I would not assign them to the sensory field but rather to our experiential reality, and there to a process that operates at a higher operational level. It is similar to looking at the skies on a clear night: you can only see an ordered pattern of stars, even a constellation, if you organise the single stars (the signals in your sensory field) by selecting some and connecting them, thus *constructing the pattern* in your mind rather than perceiving it (Glasersfeld 1999: 12; Bettoni & Eggs 2010: 133).

« 10 » Moreover, the essence of a “very radical-constructivist concept” here is not dealing with “‘perceptual’ data” (§15) but that the “object” as a generic concept, as a conceptual structure (and later many others), is constructed by organising a sensory manifold in many different ways and later by abstracting what is common to these previously constructed conceptual structures.

B | Learning as a constructive activity

« 11 » This concept used in the target article (§16) references an early article by von Glasersfeld (1983) of the same title. But I would not say that this early article presents “*matching ‘perceptual’ patterns*” as a foundation of RC. Since the fundamental epistemological principle of RC is “fit” not “match” (“viability” not “correspondence”), I would suggest avoiding the use of “match” altogether, even when it refers to sensory patterns or conceptual structures and not to pictures of the physical world.

« 12 » An elementary form of learning requires two components (Glasersfeld 1995: 152f):

- something like a memory,
- the ability to compare two signals, a present one and a goal-signal that constitutes a reference value.

Once these requirements are met, the preconditions of inductive learning are satisfied. In the event of a perturbation, all that is further needed for this elementary form of learning to occur is a rule or principle that leads the system to repeat actions that were recorded as successful in its past experience (see also de Bono 1991: 42f), thus reducing or eliminating this kind of new perturbation.

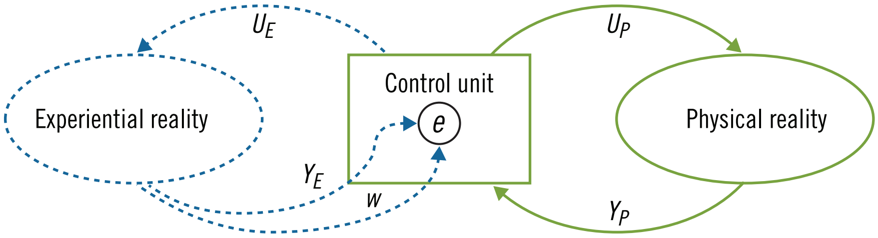

Figure 1 • The cybernetic model of viability: A coupled system of two processes controlled by one control unit. Abbreviations: Y = controlled variable; w = set point variable; e = control deviation; U = manipulated variable; index E = experiential reality; index P = physical reality.

« 13 » Although the interactions the subject has had with the world shape what will be the result of new interactions (§18), the previous knowledge that they provide is not enough for the re-cognition of a certain situation (§19; Glasersfeld 1995: 65). In fact, the sensory field provides vastly more signals than those needed for its segmentation. The organism must therefore always actively select which signals to use in order to construct either a known or a new pattern that will trigger a particular scheme, so that the pattern can be assimilated. How can the agent do this active selection? I agree with von Glasersfeld (1995: 78f) that Ceccato’s idea of an attentional system (Ceccato 1964) that produces successive pulses of attention and has the ability to form combinatorial patterns of attentional moments, can provide a model of how the mind actively selects signals in the sensory field. These pulses of attention, which I have called “attentional quanta” (Bettoni 2018), also constitute the operational structure of abstract concepts (Glasersfeld 1995: 167f). Could Ceccato’s attentional system also be implemented in the ML system for enabling it to do the needed active selection?

« 14 » Whenever a scheme is activated and the triggered activity does not yield the expected result, the discrepancy between expectation (reference value) and the experienced result creates a perturbation in the system. This perturbation is equivalent to a variation of the input into a controller unit of a control loop with negative feedback (cybernetics, control engineering). It is a novel kind of perturbation; it is not associated with a specific sensory pattern or with a specific scheme and may lead to an accommodation, an adjustment of the scheme or the formation of a new one. In this way, assimilation and accommodation enable an agent to learn.

C | The viability of conceptual structures

« 15 » I agree that we cannot “build a *real* model of this world” (§17) but I disagree with saying that we can “build a viable representation of it” because, again, our conceptual structures cannot be said to represent a real mind-independent world. They merely fit with our own experience and they are viable as means for consistently organising our experience (Glasersfeld 1983).

« 16 » In order to dive deeper into the concept of viability, I suggest making use of the language of cybernetics and control engineering. This allows us to illustrate the concept of viability by means of a *system model* (see Figure 1) where we have *one* control unit that *controls two* process units; it is a very peculiar architecture of a coupled control system with two fundamentally different processes and hence two fundamentally different, but coupled, control loops.

The control loop of physical reality

« 17 » On the right-hand side of the diagram, I differentiate between reality as a physical controlled system or process, the person as its controller and two interactions between these two units: the physical effect of a person on reality (controller output, manipulated variable U_P) and the physical effect of this reality[1] on a person (controller input, controlled variable Y_P).

« 18 » The controlled variable Y_P only affects the person in the form of a manifold (Kant 1966: B 102; Glasersfeld 1995: 40f), i.e., in an unstructured manner. In the diagram, this is indicated by the fact that the arrow ends at the periphery of the control unit and does not penetrate into the inner circle, like the other variables.

The control loop of experiential reality

« 19 » On the left-hand side of the diagram, I differentiate between the experiential world as the entirety of the experiences acquired by a person (her knowledge base) and the person as the controller in the form of a separate unit; this separation is purely heuristic in nature for illustrative purposes. In this model, I also assign to the experiential world the role of a controlled system, but a conceptual (conceptually constructed) rather than a physical controlled system.

« 20 » There are three interactions between these two units here: the conceptual effect of a person's control unit on her experiential world (manipulated variable U_E) and two conceptual effects of the experiential world on the person's control unit. The set point variable w corresponds to the goals, intentions and expectations. The controlled variable Y_E is somewhat more complicated: a person takes the controlled variable Y_P, transforms it into thought content (manipulated variable U_E), seeks to integrate this into her experiential world (assimilation, accommodation etc.) and ends up with the controlled variable Y_E.

« 21 » The control deviation e is formed from a comparison between the set point variable w and the controlled variable Y_E; this produces a binary variable e, which provides information as to whether or not there are any obstacles in the way of pursuing the goals, i.e., whether or not the current state can be deemed *viable*. If the manipulated variable U_P has led to a solution or generates any concepts that are either compatible with existing conceptual structures (lack of contradictions) or in harmony with conceptual structures that others regard as viable, then in the control unit we will obtain $e = 0$, i.e., the current state will be considered viable and will be reinforced.

Conclusion

« 22 » Diving deeper into concepts such as *the construction of experiential reality* and *learning as constructive activity* ensures that the development of an RC-framed iML will be more consistent with RC. Furthermore, due to the central role assigned to interactivity by an iML approach, the double-loop model of viability presented here could become the starting point or foundation for developing the missing "coherent conceptual framework about interactivity" that ML needs (§23). Here the model deals with a *human-world* interaction, where the human is the active agent and the world provides constraints. In ML the roles are swapped: we have to model an *ML-human* interaction, where the ML system is the active agent and the constraints are provided by the human (§30).

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1 | By "physical reality" I mean the world of constraints in which organisms live (Glasersfeld 1983) and by "physical effect" I mean variations in the sensory field due to those constraints.

References

Bettoni M. & Eggs C. (2010) User centred knowledge management: A constructivist and socialized view. Constructivist Foundations 5(3): 130 143. http://constructivist.info/5/3/130

Bettoni M. (2018) Aufmerksamkeitsquanten: Bausteine autonomen und kreativen Denkens. In: Hug T., Mitterer J. & Schorner M. (eds.) Proceedings of the Ernst von Glasersfeld Centenary Conference. Innsbruck University Press, Innsbruck.

Ceccato S. (1964) A model of the mind. Methodos 61: 3–75

de Bono E. (1991) I am right, you are wrong. Penguin Books, London.

de Bono E. (1992) Serious creativity. Harper Collins, New York.

Glasersfeld E. von (1983) Learning as constructive activity. In: Bergeron J. C. & Herscovics N. (eds.) Proceedings of the 5th Annual Meeting of the North American Group of Psychology in Mathematics Education, Vol. 1. PME-NA, Montreal: 41–101. http://cepa.info/1373

Glasersfeld E. von (1995) Radical constructivism: A way of knowing and learning. Falmer Press, London. http://cepa.info/1462

Glasersfeld E. von (1999) How do we mean? A constructivist sketch of semantics. Cybernetics and Human Knowing, 6(1): 9–16.

Kant I. (1966) Kritik der reinen Vernunft. Edited by I. Heidemann. Reclam, Stuttgart. Edition A originally published in 1781, edition B in 1787.