Emergence and Convergence: Qualitative Novelty and the Unity of Knowledge

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Context. Aggregation and generalization are two forms of abstraction essential not only in database design and use — see the classical work by Smith and Smith [1] — but also in modeling of any system, both existing and to-be-built.

Mario Bunge, a modern classic of exact philosophy, observed in the book under review (and elsewhere) that concepts are philosophical if they occur in a large number of fields of inquiry (p.77). Moreover, philosophers "won't remain satisfied with examples [...]; they will seek general patterns" (p.32). These considerations alone may explain our interest in philosophy.

Aggregation and generalization have been discussed in numerous books, papers, and standards. The best described semantics in an abstract, implementation-independent, manner while many others ignored essential semantics for various reasons including such informally expressed ones as "everyone knows what a composition is", "[the developers] will figure it out", "you cannot generate code out of your academic considerations", and so on.

Since semantics of concepts used in modeling ought to be considered even if it has not been made explicit, ignoring this semantics or hiding it "in the code" may and often does lead to failures. At the same time, by using abstraction we can discover and clearly demonstrate deep semantic analogies between seemingly (very) different systems or their fragments. This approach provides enormous help in understanding and therefore in decision making: common basic and more specific concepts need not be rediscovered and reformulated each and every time we encounter a new system or even a new situation — such as new requirements — within an existing system. Some of these common concepts and structures (such as invariant, composition (a.k.a. aggregation or "part-whole") or subtyping (a.k.a. generalization)) are encountered in all systems while some others (such as contract or trade) are more specialized.

While the classical papers by Smith and Smith [1], Codd [2] and others have laid an essential part of the foundation for further study and usage of abstraction in data, information and system modeling, additional efforts were needed to elucidate and exactify concepts used in such modeling. These efforts, based on ideas from philosophy and mathematics, were exemplified by an international standard — the Reference Model of Open Distributed Processing (RM-ODP) [3]. They have been described in detail and substantially used in various kinds of modeling (for example, [4-7]). Note that exactification essential for understanding and for communicating this understanding does not necessarily imply usage of formulas: for example, definitions in RM-ODP and those of the semantics of Algol60, as well as most legislative acts, were written in very stylized and carefully constructed English. As Bunge observed, "exactification is not identical with quantitation: there are numerous qualitative mathematical disciplines, such as logic, abstract algebra, and topology" [8]. In modeling and analysis, we discover the deep semantic analogies between various approaches to and presentations of composition and subtyping: these concepts have been exactified using property determination mechanisms, namely, emergence and convergence.

Mario Bunge's book under review is an extended survey of his work in these areas.

Text. Bunge's books are clearly written and understandable by non-experts in philosophy. Bunge notes that this book is about novelty and is addressed to the broad community of people interested in intriguing general problems (it includes a short glossary of philosophical terms used by the author). A significant prerequisite for the reader is the ability to solve new problems — Claparede's criterion of intelligence referred to by Bunge in the book.

Emergence and Convergence surveys Bunge's treatment of semantics of general systems. Abstraction and exactification are essential for understanding of systems, modeling and reasoning about them. This approach, advocated by Bunge, has been around at least since the 18th century (Adam Smith). However, it has not been consistently used in modeling IT artefacts leading to failures explained by "tinkering" (Bunge), such as box-and-line diagrams, vague or undefined semantics of various language constructs, reliance on tacit assumptions instead of "unearthing presuppositions" (p.158), etc.

A system is defined by Bunge as a complex object every component of which is related to at least one other component. More specifically, a system may be modeled as a quadruple consisting of the system's composition (collection of all parts), environment (collection of items not in it that act upon or are acted upon by certain of its parts), structure (collection of relations among its parts or among those and environmental items), and mechanism (collection of processes that make the system behave the way it does) (p.35). Thus, relationship semantics is essential for understanding of any system. Furthermore, composition and subtyping are two types of relationships essential in any kind of system modeling.

As Bunge observed in [9], modeling "involves a substantial deliberate simplification of empirical knowledge, as well as original constructs not found in experience". Bunge promotes systemism — a worldview in accordance to which every concrete thing and every idea is a system or a component of some system. Systemism is "a guide to theorizing rather than a ready-made substitute for it" (p.42). Thus, during analysis — "breaking down a whole into its components and their mutual relations" (Bunge) — we define which patterns to use and provide actual parameters for instantiating these patterns. When using the pattern of a composition we discover and formulate emergent properties of the composite, that is, properties that are not possessed by any of its components (p.17) but determined by the components and by the way the components are combined. When using the pattern of a subtyping we discover and formulate properties of a supertype that are common to all of its subtypes (that is, we deal with unity of knowledge). Composition and subtyping were treated in the same manner in RM-ODP and in another international standard — the General Relationship Model [3-7].

Bunge discusses at length complex systems of life, mind, and society which cannot be reduced to their components. He notes that "reduction, though often successful, is necessarily limited by the occurrence of emergence along with the formation of systems, and submergence along with their dismantling" (p.149). Many interesting examples are provided including that of the hyper-rationalist dogma that "all mental processes are computations performed in accordance with precise algorithms" (p.181) which led to serious harm in mathematics teaching, in computing science, and other areas. This dogma ignores such non-algorithmic mental processes as modeling, pondering (as opposed to reasoning — Dijkstra), creativity, or evaluation. One of the sad outcomes is seen in the statement by Intel CIO Doug Busch in the CIO Magazine (December 15, 2003): "It's the most destructive characteristic of large enterprises, that we're like herd animals and just do what everyone else is doing".

Interesting emergent properties of a composite describe qualitative novelties some of which are radical. Similarly, some inventions are radical while others are improvements (p.119), and this approach may be used to exactify the comparison of strategic aspects of IT with its infrastructural ones in the discussions initiated by Carr's famous article "IT doesn't matter". While certain social axioms claimed by Bunge and some of his statements in these areas appear to be invalid, they are always clearly formulated and therefore may be argued against (using Bunge's own general approaches to exact philosophy). Although the same kinds of complex phenomena of life, mind and society were lucidly discussed, often along the same lines, by F.A.Hayek in his excellent paper [10] published in a book edited by Bunge, Hayek's works were not referred to by Bunge. (Hayek uses a system of social axioms in some aspects different from that used by Bunge.)

Some interesting and useful proposals by Bunge, in particular, in the social area, may be exactified as the need to use several viewpoints of the problem domain (such as those based on biology, economy, polity and culture, p.175 and elsewhere) and to compose them, rather than to concentrate only on a single viewpoint. Again, we encounter the same ideas in RM-ODP.

"Convergence" is about unity of knowledge leading to the discovery and use of unifying principles. Exactification of these principles uses the pattern of generalization (that is, the subtyping relationship). Bunge also demonstrates how exactification helps to handle conflation — convergence of a different kind — by clarifying the distinctions between conflated concepts such as those discussed in Chapter 14 "Convergence as confusion: The case of 'Maybe'". Bunge shows how the "imprecise notions of likelihood (of events) and plausibility (of hypotheses) are treated as if they were exact. Arbitrary numbers are then used to confer scientific respectability upon mere hunches." (p.226). The need to rely on causation as opposed to chance in medical diagnosis and treatment (since "disease mechanisms are causal, not stochastic", p.263) is one of many examples. These ideas are very close to Hayek's observations of the fallacies of using statistics instead of relationship semantics: "the statistical method is of use only where we either deliberately ignore or are ignorant of the relations between individual elements with different attributes, i.e. where we ignore or are ignorant of any structures into which they are organized" [10].

Summing up, Bunge's book is of great value to the analysts (and designers) whose work is based on two complementary activities — "account of particulars" and "search for pattern" (p.282). It exactifies the still existing "debates between mindless data hunters and gatherers and those who engage in hypothesis-driven research" (p.269). And it emphasizes the need to use "the language of all the sciences, namely, mathematics" (p.283).

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