Chapter 22
General System(s) Theory 2.0: A Brief Outline

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1 Introduction

Following Bertalanffy's (1901–1972) introduction of General System Theory (GST), also known as classical Systemics [4] when intended as a corpus of concepts, approaches, or even of general social usage, the concept of system has been elaborated upon in almost all disciplinary fields, allowing inter-disciplinary approaches, including Biology, Chemistry, Cognitive Science, Economics, Education, Medicine, Physics, and Sociology.

GST, considered as General Systems Theory led to, for instance, approaches and theories such as Automata Theory, Catastrophe theory, Chaos Theory, Control theory, Cybernetics, Dissipative Structures, Games Theory, System Dynamics, and the Theory of Dynamical Systems.

2 Examples of Words and Concepts of Bertalanffy's Systemics

Examples of words and concepts used in the approaches mentioned above.

1. Anticipation;
2. Automation;
3. Completeness;
4. Computable uncertainty;
5. Context-independence;

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6. Control;
7. Decision;
8. Degrees of freedom;
9. Forecast;
10. Growth;
11. Objective;
12. Openness;
13. Optimisation;
14. Organisation;
15. Planning;
16. Precision;
17. Regulation;
18. Reversibility;
19. Separability;
20. Solvability;
21. Symbolic;
22. Standardisation;
23. Unconnectedness.

3 Examples of Words and Concepts of Post-Bertalanffy Systemics

However, following this very fecund period, new systemic approaches, concepts, and theories arose within various specific disciplines and GST also had to deal with new problems of systemics including processes of emergence and the related acquisition of new properties [16], as well as structural dynamics as occurring in phase transitions.

Below, some examples of properties which can not be dealt with using classical Systemics:

1. Coherence as the dynamic establishment of and maintaining of a property, e.g., behavioral, shape, or topological properties, established and continuously maintained through component interactions;
2. Context-dependence, i.e., non-separability from the environment;
3. Development versus growth;
4. Emergence as continuous, irregular and unpredictable but also coherent acquisition of properties such as shape and behavior;
5. Entanglement;
6. Equivalence/non-equivalence;
7. Incompleteness as a theoretical impossibility to complete or as a degree of freedom;
8. Induction of properties rather than prescriptions or solutions;
9. Irreversibility as the price of uniqueness;
10. Low-energy effects able to break equivalences or symmetries;

11. Multiplicity, including multiple systems established by the same components;
12. Networks formed by links among properties, i.e., linked properties;
13. Non-symbolic computability given, for instance, by neural networks and cellular automata;
14. Uncertainty including uncertainty principles;
15. Non-causality, non-linear but due to networked, systems of events;
16. Non-invasiveness (see Appendix);
17. Non-prescribability but possibly only inducibility;
18. Non-separability as when expressing the observed in terms of the observer;
19. Non-symbolic representations, as for neural networks;
20. Quasi- as dynamically irregular or partial, as in quasi-periodicity;
21. Role of individuality able to break equivalences;
22. Self-Organization with continuous but stable, for instance, periodic, quasi-periodic variability in the acquisition of new structures, as for Bènard rolls;
23. Simultaneity;
24. Fractality;
25. Symmetry;
26. Structural Dynamics, changes in structure over time;
27. Uniqueness, corresponding to irreversibility;
28. Usage of degrees of freedom (see Appendix).

Extensions and updates of GST concepts are not sufficient to maintain a unitary systemic theoretical framework because of the different nature of new properties and problems which require new theoretical unitary understanding.

Examples of suitable approaches are those introduced by Network Science, Meta-structures, scale-invariance, power laws, and all Quantum-based discoveries and variations as considered below.

4 General Examples of Sources of Complexity Requiring Post-Bertalanffy Approaches

While some problems have been and can be suitably treated using Bertalanffy's GST, see above list 1.1–1.23, others cannot, see list 2.1–2.28, because of their different natures. Examples of the second kind of problems occur when studying [25]:

1. Quantum effects shown, for instance, by superconductivity;
2. Nano-technologies for chemistry, pharmacology and the science of materials;
3. Problems ignored by classical approaches such as long-range correlations; biological phenomena such as the ability of the human brain to perform enormous amounts of computations in a short time using little energy; phase transitions in cognitive problems;
4. Collective systems given by the collective motion of:

- living systems provided with sufficiently complex cognitive systems such as flocks, swarms, anthills, herds, schools, crowds, and traffic where interactions between the components involve cognitive processing;
- living systems provided with no cognitive systems such as amoeba, bacterial colonies, cells, protein chains and macromolecules;
- non-living systems such as lasers, systems of boats, nano-swimmers, nematic fluids, networks, traffic signaling, rods on vibrating surfaces, shaken metallic rods—interaction involves reacting—and simple robots where interaction occurs through simple artificial cognitive systems.

5. Collective artificial systems given by collective interactions of various natures other than physical motion include communities of mobile phone networks, industrial districts, markets, morphological properties of cities and urban development, networks such as the Internet, and queues. Interaction is given by systems with cognitive processing and reactions [20].

5 Examples of Sources of Complexity for Social Systems

Social systems are able to acquire new properties thanks to increasing knowledge; processes of emergence are activated by new configurations and self-designed structural constraints given, for instance, by architecture, cultural rules and procedures. Consider the following examples:

1. knowledge-intensiveness;
2. delocalisation and globalisation;
3. duplicability;
4. highly general networked interconnections;
5. high manipulability;
6. high virtuality;
7. hyper connections;
8. importance of individuality;
9. coherences rather than equilibrium;
10. interchangeability;
11. on-line actions;
12. reduced time between design, implementation, and marketing;
13. short general lifespan;
14. technological innovations and solutions creating new problems;
15. epiphenomena, i.e., secondary phenomena occurring alongside or in parallel to the primary phenomenon;
16. multiplicity;
17. non-linearity;
18. non-sustainability;
19. augmented reality through simulations and multi-dimensional, simultaneous, and coherent information;

20. data availability (so-called Big Data);
21. networked availability of knowledge;
22. products and services come with induction for use more than directions for use;
23. rapid transformation of solutions into new problems.

6 Changing the Concept of System?

At this point we must consider that not only new kinds of systemic properties, as listed above, are being studied in various disciplines but that the concept of system itself is under examination. This occurs when the problems and properties of systemic nature are represented, for instance, as related to networks. This is the well-known case of Network Science (see, for instance, [1, 3, 9–11, 19, 28]) where phenomena and problems are represented as networks (interdisciplinarity) and systemic properties are the properties of such networks (transdisciplinarity).

Emergent systemic properties are considered to be represented by properties of networks. The selection of nodes and links, i.e., what is to be considered as such; the kind of networks, such as scale-free, random and hierarchical; their properties, topological, scale-freeness, small worldness; modularity as a measure of the structure of networks, when detecting community structures in networks, should be considered as *a new way to represent systemic properties*.

Because of this, Network Science is often considered as the new post-Bertalanffy systems science even though other approaches should be considered, such as (a) quantum systems, which allow a number of different representations, critical interaction with the environment, and dissipation [5, 6, 8, 12, 21], when considering a possible quantum Systemics and (b) meta-structures [16, 18]. Other cases occur for collective behaviors when considering scale invariance and power laws [23], entropy [24], and topological distances [22]. When considering the DYnamical uSage of Models (DYSAM, [17, pp. 64–85]) we should look for multiple, eventually subsequent, simultaneous, and superimposed approaches to consider and model systemic properties. A new form of reductionism would be to consider one approach as unique and universal.

7 Conclusions

The first part introduced some specific aspects and concepts of classical Bertalanffy Systemics, whereas the second listed some specific aspects and concepts related to levels of complexity which cannot be approached using classical Systemics or its extensions since they are of a different nature. The third part listed examples of problems and sources possessing and generating such new situations. The fourth and last part listed examples of sources and generators of such new situations with particular reference to social systems.

We conclude by stressing that, on the one hand, the new Systemics 2.0 is not an extension of classical Systemics, but that they are expected to coexist with classical Systemics, the approaches used being possible combinations of the two Systemics at different levels. This corresponds to the fact that phenomena should be intended as combinations of functioning and emergence, and of various possible, even superimposed, representations as considered by the DYnamic uSAge of Models (DYSAM) based on strategies using independent and irreducible models as applied in well-established approaches such as the Bayesian method, Ensemble Learning, Evolutionary Game Theory, Machine Learning, Second-Order Cybernetics, and Pierce's abduction [13], [17, pp. 64–75]. There will be possible usages of one Systemics by the other.

There are overlapping fuzzy areas between the two Systemics, which are not comparable and neither is their systemic power. Approaches belonging conceptually to the former Systemics could be used to model complex phenomena, such as strange attractors for chaotic phenomena.

We conclude by stressing that the usage of Bertalanffy Systemics to deal with problems and properties of complex phenomena is to be considered as a new form of reductionism.

Appendix

This appendix presents three examples of cases using the new approaches considered by Systemics 2.0.

Orders to Complex Systems?

It is ineffective to give symbolic, explicit orders to sub-symbolic, non-explicit and emergent systems since they cannot process them. The symbolic and emergent natures are contradictory.

Possible actions cannot be explicitly prescribed but submitted in such a way as to allow their being suitably processed.

For instance, actions upon various properties of collective behaviors may relate to the environment such as using perturbations, inserting possibly dynamic obstacles, inserting perturbative phenomena such as other collective behaviors; actions upon communication between elements by using language, symbols and technologies as well as to the energy available. Orders should be translated into suggestions, contextual changes, information, and interactions to be suitably processed by the system as when using the assumption of non-invasiveness or using low energy approaches.

Non-invasiveness and Low Energy

Non-invasiveness is suggested by the limited strategic value of explicitly prescribing, or administering behavior for establishing states as mentioned above. The use of soft, low-energy approaches is very important as they do not require system interventions or the administration of intense sources of energy assuming it to be processed as through communicating vessels (like feeding a parking meter with a 10-cent coin and not with a 50-Euro banknote ...).

The assumption is that feeding the maximum is always an optimum strategy leaving the system to dose the amounts required.

However, in the latter case, the overloaded system can not explore equivalent spaces of states and trajectories from which to choose on the basis of low-energy fluctuations and influences of any kind. This relates to fundamental research in theoretical biology, for instance, by Erwin Bauer (1890–1938) who considered living systems as being different from physical ones because they do not consume the supplied energy immediately, being able to manage it.

Life would be inextricably involved in the succession and maintaining of coherence between processes of emergence and changes between the coherences of various possible states of equilibrium. One searches for coherence rather than equilibrium, coherence between multiple and dynamic equilibria, levels of coherence.

Examples exist in medicine where combinations of invasiveness and non-invasiveness occur. Any invasive interventions such as the insertion of devices, e.g., pacemakers, prostheses, transplanted organs, or removal, e.g., damaged or infected organs, should be processed, i.e., accepted and even recognized by the living system. Levels of pharmacological treatment combine different degrees of invasiveness and non-invasiveness up to the extremes of psychological treatment, as in the placebo effect [7].

Between Degrees of Freedom

Another non-invasive approach used to influence systems is the setting of suitable variable degrees of freedom to the behavior of interacting agents.

However, a more interesting aspect appears when considering not only degrees of freedom as for mechanical devices and procedures, but how they are used. For instance, while respecting the degrees of freedom, a number of generic agents use them at (a) the maximum or (b) minimum levels or (c) in regular oscillating or completely random ways [14]. The degrees of freedom DF, say $DF = [Max\,allowed - Min\,allowed]$ may be used at different percentages and may adopt different temporal sequences. Such temporal sequences should be intended as behavioral profiles, irrelevant at macroscopic levels but significant at microscopic levels and in determining mesoscopic properties.

Another example is given by the structuring of space in which agents interact, as in urban planning when deciding the shape and size of roads, the inclusion of roundabouts and speed bumps in order to influence the properties of traffic, crowd evacuation in case of emergency or managing long queues; rooms in schools, hospitals and offices [2, 15, 26, 27, 29].

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