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Toward a Theoretical Framework: How Can Knowledge Organization Systems Be Understood Through the Lens of Complex Systems?

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Abstract

Knowledge organization systems display network properties that align them with complex systems, even though the Information Science field has largely overlooked this framework. Drawing on historical precedents and mathematical evidence (e.g., the logistic equation) as well as mapping power-law and small-world behaviors in semantic networks, this paper provides a theoretical framework to model KOS as complex adaptive structures. While some decry the discipline's "epistemological promiscuity," such eclecticism serves as a necessary toolkit for decoding knowledge infrastructures that no longer fit into rigid silos. By bridging complexity science and knowledge organization (KO), this text offers a novel lens for interpreting how these systems evolve. Viewing knowledge organization systems through the lens of complex systems is not merely an academic exercise: it delivers the conceptual and theoretical basis to counter algorithmic dominance and systemic misinformation.

Keywords: complex systems; knowledge organization systems; network science; information science.

1.0 Introduction

Knowledge Organization Systems (KOSs) – including ontologies, taxonomies, classifications, and thesauri – constitute a fundamental pillar of Information Science. Traditionally, these systems have been conceived as static, hierarchical semantic

structures designed to capture conceptual relationships in a consistent and durable manner (Gruber 1993; Guarino 1998). This approach assumes that knowledge can be contained in relatively immutable artifacts (Hjørland 2008).

However, contemporary digital infrastructures – such as large-scale semantic networks (DBpedia, Wikidata), collaborative open repositories, and Linked Data – reveal dynamics that challenge the static arrangement. When analyzed in their actual operation and evolution, ontologies and thesauri display growth patterns, reorganization, and resilience that suggest the presence of nonlinearity, conceptual emergence, self-organization, and network topologies resembling scale-free and small-world structures (Barabási and Albert 1999; Watts and Strogatz 1998; Newman 2018).

If ecosystems, financial markets, and epidemics are complex systems, what authorizes us to think that knowledge – perhaps the most intricate product of human cognition – would be less so? Information Science is not immune to this question (Bates 2005; Buckland 2012). As Bizer et al. (2009) document, large-scale knowledge graphs reveal properties that demand analytical frameworks beyond traditional hierarchical models.

Within the scope of Knowledge Organization (from 2010 to date), only one article addressed Complex Systems (Bonome 2012) – a striking gap given the field's seven-decade trajectory. Information Science must engage with complexity to confront transformations reshaping knowledge production, mediation, and appropriation. This paper introduces a theoretical reflection on the interfaces between Complex Systems Theory and the KOS analysis. More than an exhaustive literature review, it aims to be an essay seeking to articulate concepts from network science, nonlinear dynamics, and formal knowledge representation (Tennis 2008). The research objective is to offer an alternative interpretive lens for phenomena already observed in the literature, in addition to identifying promising directions for future investigations.

The remainder of this paper is structured as follows: Section 2 presents the methodological approach, while Section 3 introduces the fundamentals of Complex Systems Theory relevant to KOS analysis. Section 4 synthesizes empirical findings on complex properties in semantic networks, and Section 5 discusses implications for theory and practice. Finally, Section 6 concludes with an agenda for future research.

2.0 Methodology

The present article is an exploratory theoretical study, with a qualitative approach. It aims at constructing a conceptual framework for analyzing Knowledge Organization Systems through the lens of Complex Systems Theory. According to Demo (2000), theoretical research is dedicated to reconstructing theories, concepts, and ideas. In doing so, we use available knowledge as raw material to produce new syntheses and perspectives.

The methodological course comprised the following phases:

Phase 1 – **Literature review**: A structured literature search was carried out in Knowledge

Organization (KO), the Journal of the Association for Information Science and Technology (JASIST), the CAPES Portal, Scopus, Web of Science, and Google Scholar. The following search string was applied: ("ontology" OR "knowledge organization system" OR "semantic network") AND ("complex systems" OR "network science" OR "nonlinear dynamics"). To be eligible, studies had to be published between 2000 and 2026, written in English or Portuguese, and presenting mathematical modeling or structural analysis of KOSs. The final corpus was predominantly composed of English-language publications.

Phase 2 – Conceptual mapping and categorization: From the reviewed literature, inductive thematic analysis was conducted to identify recurring dimensions of complexity in KOSs. Data collection and multi-level text annotation (e.g., sentence-level) were used to structure empirical inputs.

Phase 3 – Integration and framework proposition: We articulated the identified categories into an integrative framework, organizing the dimensions of complexity into analytical layers and specifying their relationships.

Limitations: The theoretical nature of the framework demands subsequent empirical validation through case studies or computational simulations.

3.0 Complex Systems and Knowledge Organization

A complex system can be formally represented as $S=(E,I,F)$ where “E” captures the set of entities, “I” denotes the interactions between these entities, and “F” defines the rules governing the system's dynamics. In the context of knowledge organization, entities may correspond to concepts, documents, or authors, while interactions may represent semantic relationships, citations, or conceptual connections.

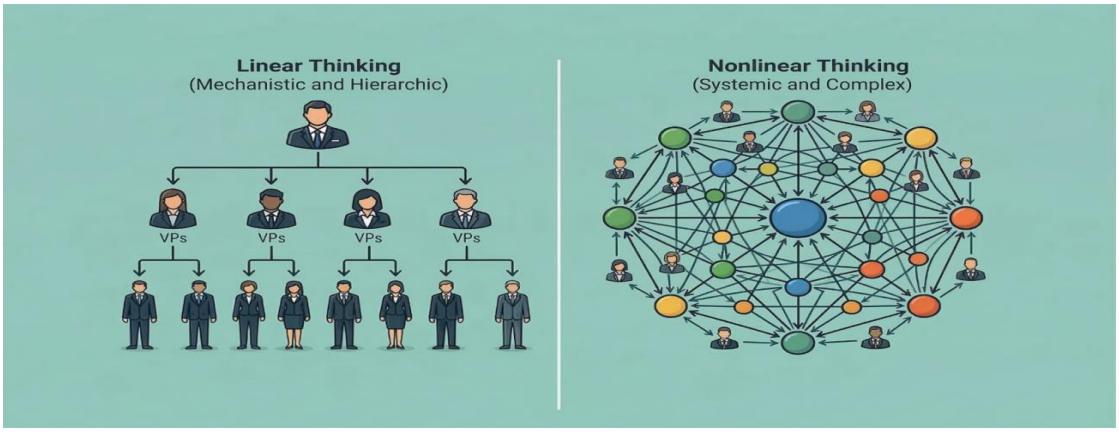

Figure 1. Comparison of systems of thought and organization

As established by the seminal propositions of Mitchell (2009) and Holland (1998), a complex system is characterized by the dynamic interaction of multiple components, whose collective behaviors are irreducible to the isolated properties of their parts.

Emergence, nonlinearity, and self-organization are not mere epiphenomena but fundamental properties of systems where information processing allows global patterns to arise from local interaction rules.

Simon (1991, 468) provides a foundational definition: "[A] complex system ... [is] ... one made up of a large number of parts that interact in a non-simple way. In such systems, the whole is more than the sum of its parts... in the important pragmatic sense that, given the properties of the parts and the laws of their interaction, it is not a trivial matter to infer the properties of the whole."

For practical purposes, we here adopt Mitchell's (2009, 13) definition: *a system with a large number of interacting agents that exhibits nontrivial emergent and self-organized behaviors*.

3.1 Historical and Conceptual Analysis

Complexity Science consolidated in the 20th century from the realization that the reductionist-linear paradigm was insufficient to understand the dynamics of biological and social systems. Its foundations were established by General Systems Theory (von Bertalanffy) and Cybernetics (Wiener). These approaches shifted scientific emphasis from a fragmented situation to the study of interactions and feedback loops.

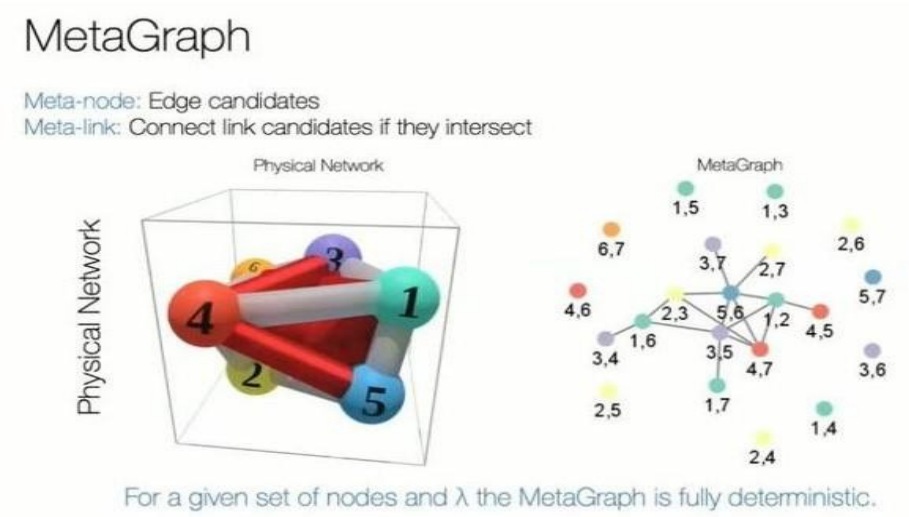

Figure 2. Mathematical models of informational dynamics (Barabási 2016).

In bibliometric studies, researchers use the *MetaGraph* approach to recontextualize relationships (e.g., co-citations and co-authorships) as the primary unit of analysis, uncovering latent thematic clusters and mapping the interdisciplinary evolution of scientific knowledge with enhanced precision.

In Information Science, for instance, bibliometrics reflects the logic of complex systems by

tracing relationships among authors, documents, and ideas across time and space (Price 1965). The MetaGraph approach emphasizes relational structures, such as co-authorship and co-citation networks, to identify thematic clusters and informational flows (Basu and Blanning 2007). Through network analysis, it makes the interdisciplinary evolution of science more visible (Leydesdorff 2007), showing that bibliometrics and complex systems have long been closely intertwined in practice.

The consolidation of the field of Complexity Science occurred with the formalization of Complex Adaptive Systems (CAS), advanced by researchers at the Santa Fe Institute. Holland and Kauffman established that order can emerge spontaneously, without centralized control, through self-organization and evolutionary algorithms (Holland 1975). As explored by Gell-Mann (1994) and Mitchell (2009), the capacity of these systems to adapt and generate emergent behaviors revealed complexity as an inherent property of organized matter.

At the threshold of the 21st century, network theory, notably with the works of Barabási and Newman, established the mathematical bases for understanding global interconnectivity. They demonstrated the universality of connectivity rules governing everything from technological infrastructures to epidemiological dynamics (Barabási 2016; Newman 2010).

Table 1 Chronological evolution of Complexity Science and Systems Theory (1950s–2020s)

1950s–1980s	2000s–2020s
#1 Ludwig von Bertalanffy 1950s - Univ. of Vienna *General System Theory (1968)*	**#9 Mark Newman** 2000s - Univ. of Michigan *Networks (2010)*
#2 Norbert Wiener 1950s - Harvard University *Cybernetics (1948)*	**#10 Albert-László Barabási** 2000s - Northeastern University *Emergence of Scaling in Random Networks (1999)*
#3 William Ross Ashby 1950s - Univ. of Cambridge *Design for a Brain (1952)*	**#11 Melanie Mitchell** 2010s - Santa Fe Institute *Complexity: A Guided Tour (2009)*
#4 Ilya Prigogine 1960s - Univ. Libre de Bruxelles *Self-Organization in Non-Equilibrium Systems (1977)*	**#12 Dirk Helbing** 2000s - ETH Zurich *Self-Organized Pedestrian Movement (2001)*
#5 John Holland 1970s - University of Michigan *Adaptation in Natural and Artificial Systems (1975)*	**#13 Giorgio Parisi** 2020s - Sapienza University of Rome *In a Flight of Starlings (2022)*
#6 Murray Gell-Mann 1980s - Santa Fe Institute	**#14 Yaneer Bar-Yam** 2010s - NECSI

The Quark and the Jaguar (1994)	*Dynamics of Complex Systems (2011)*
#7 Stuart Kauffman 1990s - Santa Fe Institute *The Origins of Order (1993)*	**#15 Hiroki Sayama** 2010s - Binghamton University *Introduction to the Modeling and Analysis of Complex Systems (2015)*
#8 Heinz von Foerster 1950s - University of Illinois *Observing Systems (1981)*	**#16 Scott E. Page** 2010s - University of Michigan *The Model Thinker (2018)*

Table 1 synthesizes the intellectual trajectory of Complexity Science, mapping its evolution from the foundations of General Systems Theory and Cybernetics in the 1950s to contemporary advances in disordered systems physics and complex systems.

3.2 Temporal Dynamics in Information Systems

Beyond network structure, information systems demonstrate temporal dynamics modeled by nonlinear **ordinary differential equations** (**ODEs**) of the general form: "$dx/dt = F(x,t)$", where "x(t)" is the system's state vector and "F" is a nonlinear function. In informational contexts, these ODEs describe the evolution of scientific domains, such as the growth of publications or semantic concepts.

A classic example is the **logistic equation**, $dP/dt = rP(1-P/K)$, which captures initial exponential growth followed by saturation (Verhulst 1838; Murray 2002). The model determines the system's growth velocity (**dP/dt**) based on its current state (**P**) and intrinsic rate (**r**), whilst the term (**1 - P/K**) acts as an environmental brake that decelerates the process as it approaches its maximum carrying capacity (**K**). This sigmoidal pattern applies both to populations and to scientific domains as they mature (Price 1965; Bornmann and Mutz 2015). Within the scope of complex systems, the logistic equation constitutes a fundamental mathematical tool to analyze the temporal evolution of processes constrained by internal or external restrictions.

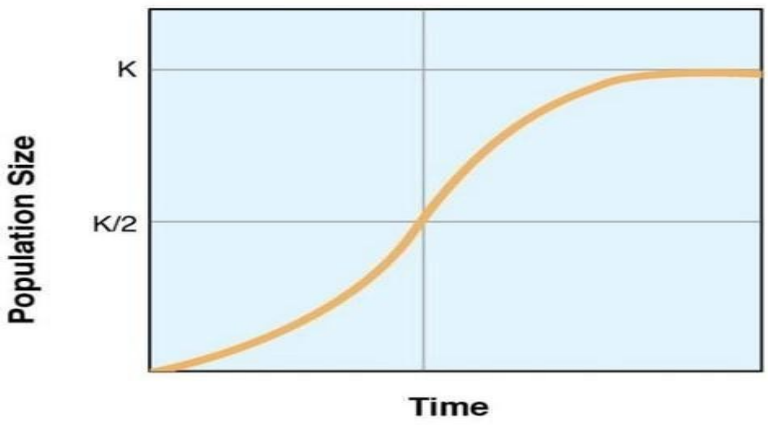

Figure 3. Mathematical models of informational dynamics

The versatility of this formulation allows it to be applied to the analysis of epidemics, demographics, market saturation, and information dissemination, demonstrating that natural systems operate under complex patterns of regulation and continuous adaptation. In this regard, such a mathematical approach can help elucidate the evolution of a given knowledge organization system — a task that represents a contemporary scientific challenge, given the complexity imposed by today's immense volume of data (Price 1963).

4.0 Empirical Evidence: KOSs as Complex Networks

Recent studies have documented, albeit in fragmented form, evidence corroborating the hypothesis that KOSs exhibit complex properties. Analyses of DBpedia's topology reveal connectivity distributions following power laws, characteristic of scale-free networks (Auer et al. 2007; Bizer et al. 2009). Investigations into the evolution of Gene Ontology identify growth patterns resembling complex adaptive system dynamics (Varley 2025).

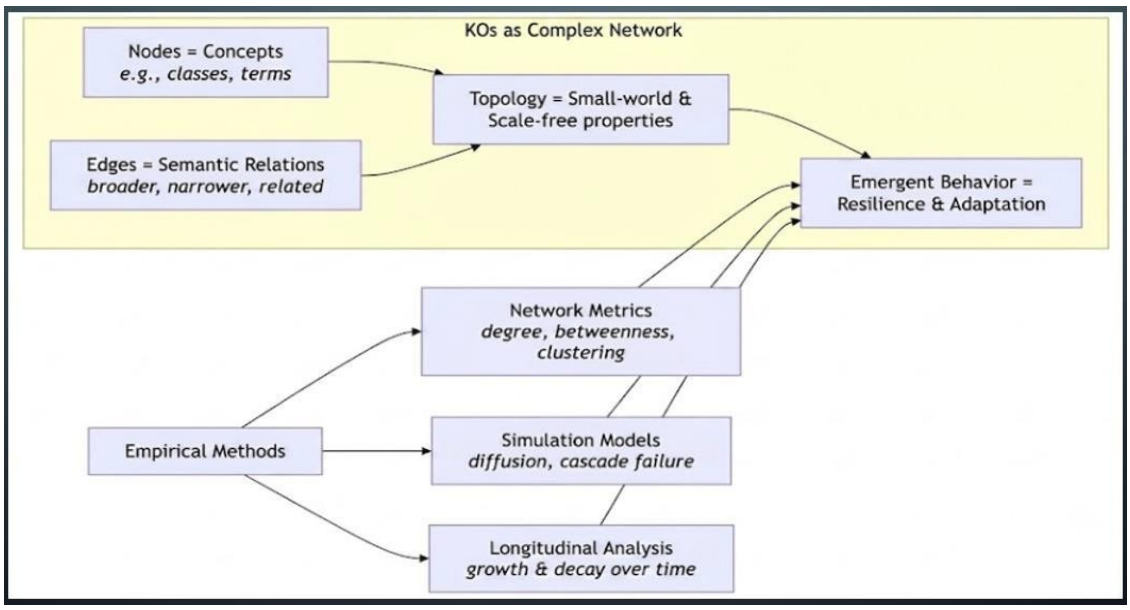

Figure 4. KOS as complex networks: nodes, emergence, and empirical methods.

Collaborative thesauri, in turn, exhibit self-organization behaviors and differential robustness to perturbations, suggesting the operation of mechanisms similar to those observed in resilient complex networks (Mediano et al. 2025). Figure 4 provides a conceptual diagram that illustrates the modeling of Knowledge Organization Systems as complex networks.

5.0 Discussion: Implications and Challenges

5.1 Theoretical Implications

The convergence between Complex Systems Theory and Knowledge Organization carries profound theoretical implications. First, it displaces the analytical focus from knowledge as a stable product to knowledge as an adaptive process, aligning Information Science with contemporary epistemological debates about the nature of complex informational phenomena (Hjørland 2016). Second, it introduces a vocabulary and mathematical machinery suitable to capture the dynamics often obscured by static hierarchical models (Sayama 2015).

The notion of semantic robustness – here outlined from dialogue with network science – illustrates the heuristic potential of this perspective: central concepts in an ontology are not merely well-connected nodes but inflection points whose removal can trigger unpredictable reconfigurations throughout the system.

5.2 Methodological Challenges and Gaps

Despite the promise of the approach outlined in the preceding section, significant challenges persist. The absence of unifying frameworks articulating structural metrics (centrality, modularity, assortativity) with dynamic models (evolution equations, robustness analysis) constitutes the main barrier to advancing the area (Hjørland 2016; Soergel 2019). Additionally, there is a lack of epistemological reflection situating this approximation within the broader context of Information Science, critically evaluating the limits and possibilities of conceptual importation between fields.

From an epistemological standpoint, the proposed approximation cannot ignore warnings about the risks of **uncritical eclecticism** and **"epistemological promiscuity"** that characterize certain interdisciplinary appropriations in Information Science (Fuller et al. 2013). The importation of concepts from Complex Systems Theory should demand permanent epistemological vigilance, ensuring that the analytical categories employed are adequate to the specificity of informational phenomena and not mere mechanical transpositions from other domains.

5.3 Practical Implications

If ontologies, for example, behave as complex systems (Table 2) – if their evolution is nonlinear, their structure emergent, their robustness differential –, then governance strategies based on linear and static models may be insufficient (Holland 1995).

Such strategies may even be counterproductive for ensuring adaptability and resilience in dynamic digital environments (Mitchell 2009). Understanding KOSs as complex systems is therefore not a theoretical luxury but a practical necessity for dealing with the growing complexity of the contemporary informational ecosystem. This has direct implications for the curation of large volumes of semantic data (Bizer et al. 2009), interoperability between information systems, and the development of artificial intelligence applications that

depend on formal knowledge representations (Preskill 2024).

Table 2 Key points of complex systems epistemology

Epistemological Mapping of Complex Systems		
Complexity and Organization	**Dynamics and Instability**	**Epistemology and Observation**
Interconnected Patterns	Chaos	Intersubjectivity
Complex Systems	Entropy Law	Multi-versa
Structural Closure	Indeterminacy	Reflexivity
Networks of Networks	Order from Fluctuation	Reality Construction
Complexity, Disorder	Physics of processes	Self-Reference
Ecosystemic Connections	Crisis	Transdisciplinarity

The theoretical framework Complexity of Organization of Dynamic Domains of Data, Information and Knowledge (CODDIK) is a schematic representation of the small-world network topology characterizing dynamic knowledge domains (Figure 5). Nodes and edges delineate the structural configuration of data, information, and knowledge systems, incorporating ontological foundations, curatorial mechanisms, and socio-dynamic interactions. This conceptual architecture describes nonlinear dynamics, emergent properties, systemic resilience, and adaptive capacity, emphasizing the roles of connectivity, heterogeneity, and critical transitions in shaping the evolutionary trajectories of complex adaptive systems.

6.0 Conclusion and Research Agenda

This essay has explored the conceptual foundations and analytical potential of applying complex systems theory to ontologies, thesauri and other knowledge organization systems. The critical review of the literature reveals KOSs as dynamic semantic networks, whose behavior can be modelled through the lens of complexity science.

First aim – examining concepts from complex systems theory and their relevance to KOSs. Emergence, nonlinearity, self-organization, and network topologies find direct parallels in the structure of contemporary ontologies. Concepts such as power-law distributions and clustering coefficients can be transferred to semantic networks, provided adequate epistemological mediation is observed (Barabási 2016; Watts and Strogatz 1998; Newman 2018).

Second aim – synthesizing findings on complex properties in ontologies. DBpedia features power-law distributions (Auer et al. 2007; Bizer et al. 2009). Gene Ontology displays growth patterns typical of adaptive systems (Varley 2025). Collaborative thesauri show self-organization and differential robustness (Mediano et al. 2025). Such properties are recurrent in KOSs, demanding specific analytical frameworks.

Third aim – identifying gaps in cross-disciplinary integration. Frameworks unifying structural metrics (centrality, modularity) with dynamic models (evolution equations, robustness) are lacking (Hjørland 2016; Soergel 2019). Epistemological reflection on the limits of conceptual importation is also necessary (Fuller et al. 2013).

Fourth aim – proposing a research agenda. Future directions include: (a) hybrid structure-dynamics metrics; (b) longitudinal studies of KOS growth; (c) investigation of semantic robustness; (d) comparative analysis across KOS types (formal ontologies, collaborative thesauri, folksonomies).

The limitations of this study stem from its essayistic nature. It is a theoretical reflection without empirical validation of the propositions presented. Future studies may employ agent-based simulations, longitudinal analyses, and mathematical modeling to test the explanatory power of the framework outlined here.

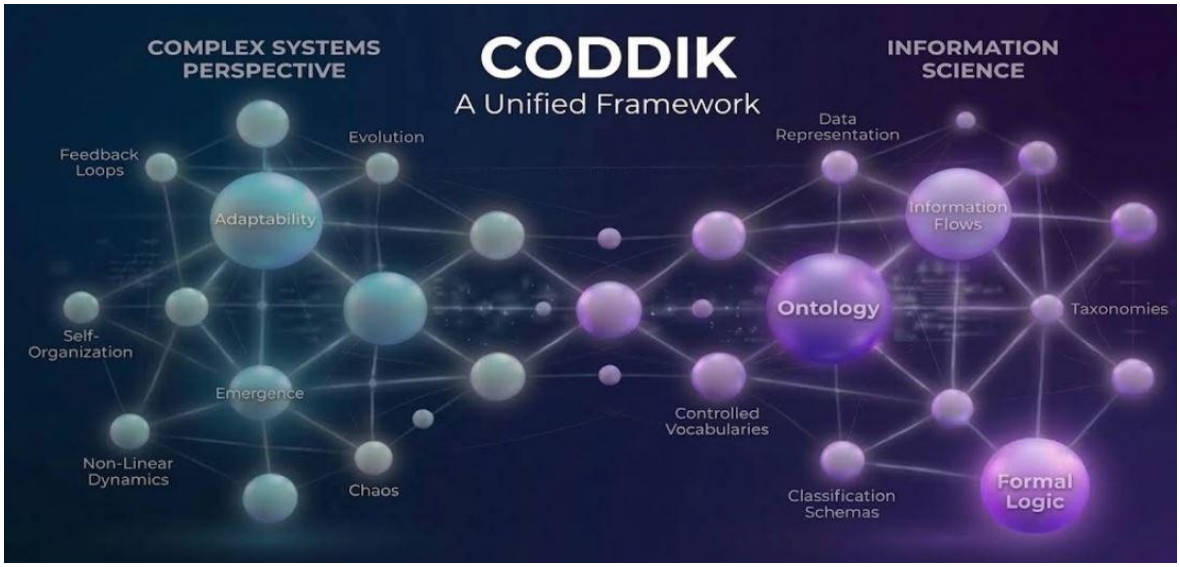

Figure 5. The heuristic framework—CODDIK

The **CODDIK** – a heuristic framework between **Complex Systems** and **Information Science** – proves necessary given the complexity of the contemporary informational ecosystem. Since knowledge is inherently dynamic and relational, representing it through static structures may hinder interoperability, curation, and the development of intelligent systems.

A central question remains: How to translate the mathematical and conceptual sophistication of complex systems theory into operational tools accessible to information professionals, while retaining the analytical rigor that powers its explanatory force? **The answer will determine whether complex systems research remains confined to theoretical debate or reshapes knowledge organization practices.**

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DeepSeek-V4-Flash and Gemini 3.5 Flash (https://gemini.google.com/) helped us brainstorm, structure the sections, refine the language, and synthesize the literature, while Gemini also assisted with the figures (e.g. Figure 5). We closely reviewed and verified all AI-generated suggestions, and we take full responsibility for the accuracy and integrity of our manuscript.

References

Auer, Sören, Christian Bizer, Georgi Kobilarov, Jens Lehmann, Richard Cyganiak, and Zachary Ives. 2007. “DBpedia: A Nucleus for a Web of Open Data.” In The Semantic Web: 6th International Semantic Web Conference, 2nd Asian Semantic Web Conference, edited by Karl Aberer, Key-Sun Choi, Natasha Noy, Dean Allemang, Kyung-Il Lee, Lyndon Nixon, Jennifer Golbeck, et al., 722–735. Lecture Notes in Computer Science 4825. Berlin: Springer. doi: 10.1007/978-3-540-76298-0_52.

Barabási, Albert-László. 2016. Network Science. Cambridge: Cambridge University Press.

Barabási, Albert-László, and Réka Albert. 1999. “Emergence of Scaling in Random Networks.” Science 286: 509–512.

Basu, Amit, and Robert W. Blanning. 2007. Metagraphs and Their Applications. New York: Springer.

Bates, Marcia J. 2005. “Information and Knowledge: An Evolutionary Framework for Information Science.” Information Research 10, no. 4: paper 239.

Bizer, Christian, Tom Heath, and Tim Berners-Lee. 2009. “Linked Data: The Story So Far.” International Journal on Semantic Web and Information Systems 5: 1–22. doi: 10.4018/jswis.2009081901.

Bornmann, Lutz, and Rüdiger Mutz. 2015. “Growth Rates of Modern Science: A Bibliometric Analysis Based on the Number of Publications and Cited References.”

Journal of the Association for Information Science and Technology 66: 2215–2222.

Buckland, Michael. 2012. “What Kind of Science Can Information Science Be?” Journal of the American Society for Information Science and Technology 63: 1–7.

Demo, Pedro. 2000. Metodologia do conhecimento científico. São Paulo: Atlas.

Fuller, Steve, Birger Hjørland, Fidelia Ibekwe-SanJuan, Lai Ma, Jens Erik Mai, Joseph Tennis, and Julian Warner. 2013. “Uncovering Epistemological Assumptions Underlying Research in Information Studies.” Proceedings of the American Society for Information Science and Technology 50: 1–4. doi: 10.1002/meet.14505001015.

Furner, Jonathan. 2010. “Philosophy and Information Studies.” Annual Review of Information Science and Technology 44: 159–200.

Gell-Mann, Murray. 1994. The Quark and the Jaguar: Adventures in the Simple and the Complex. New York: W. H. Freeman.

Gruber, Thomas R. 1993. “A Translation Approach to Portable Ontology Specifications.” Knowledge Acquisition 5: 199–220.

Guarino, Nicola. 1998. “Formal Ontology and Information Systems.” In Formal Ontology in Information Systems: Proceedings of FOIS ’98, edited by Nicola Guarino, 3–15. Amsterdam: IOS Press.

Hjørland, Birger. 2002. “Epistemology and the Socio-Cognitive Perspective in Information Science.” Journal of the American Society for Information Science and Technology 53: 257–270. doi: 10.1002/asi.10042.

Hjørland, Birger. 2008. “What Is Knowledge Organization (KO)?” Knowledge Organization 35: 86–101.

Hjørland, Birger. 2013. “Information Science and Its Core Concepts: Levels of Disagreement.” In Fundamental Notions of Information, Communication and Knowledge: Its Affect on Scientific Research and Interdisciplinarity, edited by Fidelia Ibekwe-SanJuan and Thomas M. Dousa, 205–235. Dordrecht: Springer. doi: 10.1007/978-94-007-6973-1_9.

Hjørland, Birger. 2016. “Knowledge Organization (KO).” Knowledge Organization 43: 475–484. doi: 10.5771/0943-7444-2016-6-475.

Holland, John H. 1975. Adaptation in Natural and Artificial Systems. Ann Arbor: University of Michigan Press.

Holland, John H. 1995. Hidden Order: How Adaptation Builds Complexity. Reading, MA: Addison-Wesley.

Holland, John H. 1998. Emergence: From Chaos to Order. Oxford: Oxford University Press.

Leydesdorff, Loet. 2007. “Betweenness Centrality as an Indicator of the Interdisciplinarity of Scientific Journals.” Journal of the American Society for Information Science and Technology 58: 1303–1319.

Mediano, Pedro A. M., Fernando E. Rosas, Andrea I. Luppi, Robin L. Carhart-Harris, Daniel Bor, Anil K. Seth, and Adam B. Barrett. 2025. “Toward a Unified Taxonomy of Information Dynamics via Integrated Information Decomposition.” Proceedings of the National Academy of Sciences 122: e2423297122. doi: 10.1073/pnas.2423297122.

Mitchell, Melanie. 2009. Complexity: A Guided Tour. Oxford: Oxford University Press.

Murray, James D. 2002. Mathematical Biology I: An Introduction. 3rd ed. New York: Springer.

Newman, Mark E. J. 2010. Networks: An Introduction. Oxford: Oxford University Press.

Newman, Mark E. J. 2018. Networks. 2nd ed. Oxford: Oxford University Press.

Preskill, J. 2024. “Quantum Computing and the Entanglement Frontier.” Physics Today 77, no. 2: 34–40.

Price, D. J. de S. 1963. Little Science, Big Science. New York: Columbia University Press.

Price, D. J. de S. 1965. “Networks of Scientific Papers.” Science 149: 510–515.

Prigogine, Ilya. 1980. From Being to Becoming: Time and Complexity in the Physical Sciences. San Francisco: W. H. Freeman.

Prigogine, Ilya, and Isabelle Stengers. 1984. Order Out of Chaos: Man’s New Dialogue with Nature. New York: Bantam Books.

Sayama, Hiroki. 2015. Introduction to the Modeling and Analysis of Complex Systems. Geneseo, NY: Open SUNY Textbooks.

Simon, Herbert A. 1991. “The Architecture of Complexity.” In Facets of Systems Science, edited by George J. Klir, 457–476. New York: Springer.

Soergel, Dagobert. 2019. “Knowledge Organization Systems: Overview.” Encyclopedia of Library and Information Sciences 4: 2680–2691.

Tennis, Joseph T. 2008. “Epistemology, Theory, and Methodology in Knowledge Organization: Toward a Classification, Metatheory, and Research Framework.” Knowledge Organization 35: 102–112.

Varley, Thomas F. 2025. “Information Theory for Complex Systems Scientists: What, Why, and How.” Physics Reports 1148: 1–55. doi: 10.1016/j.physrep.2025.09.007.

Verhulst, Pierre-François. 1838. “Notice sur la loi que la population poursuit dans son accroissement.” Correspondance Mathématique et Physique 10: 113–121.

Watts, Duncan J., and Steven H. Strogatz. 1998. “Collective Dynamics of ‘Small-World’ Networks.” Nature 393: 440–442.