

THE ROLE OF SIMILARITY IN COMPLEX SYSTEMS AND SYSTEM COLLABORATION: A FRAMEWORK FOR BALANCING HOMOGENEITY AND HETEROGENEITY

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Abstract

In an era marked by globalization and rapid technological change, modern systems face growing complexity, uncertainty, and dynamic interdependence. Although similarity is essential in shaping system structures and collaborative behavior, prior research lacks an integrated framework for understanding its role in complex systems. This study proposes the High-Low Similarity Component Model (HLSCM), grounded in General Systems Theory and Complex Adaptive Systems Theory, to fill this gap. The model conceptualizes systems as comprising High-Similarity Components (HSC), which support stability, compatibility, and universality, and Low-Similarity Components (LSC), which enable agility, adaptability, and uniqueness. These components are identified based on the degree of similarity among system elements. The HSC represent the homogeneous aspects of the system, while the LSC reflect its heterogeneous features. The interplay between HSC and LSC allows systems to balance homogeneity and heterogeneity in evolving contexts. Furthermore, this study introduces a similarity feedback loop, in which interaction relationships both arise from and reshape similarity structures, creating a recursive, co-evolutionary process. A dynamic balancing mechanism is also proposed to explain how systems navigate tensions between HSC and LSC through principles of functional coordination, adaptive modulation, and tensional balance. Altogether, this research offers a similarity-based framework for systemic analysis, helping scholars and practitioners identify critical similarity components, optimize similarity configurations, and manage collaborative tensions to achieve optimal similarity in complex, dynamic environments.

Keywords

Similarity, Similarity System, Complex Systems, System Collaboration, System Theory

1 | Introduction

In today's highly interconnected and dynamically evolving socio-economic environment, understanding the operational mechanisms of complex systems has become a central theme in system research and management science. Whether in strategic alliances between firms, cross-organizational collaborations, or the synergistic interplay between artificial intelligence and human workers, the patterns of interaction between systems significantly determine the overall efficiency and performance. Nevertheless, many key factors that influence system collaboration remain poorly understood. In recent years, similarity has emerged as a critical variable shaping system relationships, gradually attracting increasing scholarly attention. Existing studies have demonstrated that similarity affects trust-building (Ozdemir, Zhang, Gupta, & Bebek, 2020), information exchange (Ertug, Gargiulo, Galunic, & Zou, 2018), and innovation performance (Zhang & Hu, 2017). However, similarity is not a unidimensional concept. It spans cognitive, structural, functional, and behavioral dimensions, and its impacts are not always positive. On one hand, similarity promotes smoother coordination, better communication, and higher levels of trust among system actors. On the other hand, it can also reduce the diversity of knowledge, perspectives, and resources that actors can access (Ertug, Brennecke, Kovács, & Zou, 2022). Consequently, comprehending the role of

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similarity in complex systems and developing a systemic theoretical framework is crucial for revealing the essence of system collaboration and optimizing management strategies.

In systems science, similarity represents the commonalities shared by systems. General Systems Theory (GST) posits that all systems exhibit universal principles at certain levels, such as input-output relationships, feedback mechanisms, and openness (Bertalanffy, 1968). Living Systems Theory further contends that biological and social systems share similar patterns in information transmission, material flows, and energy exchanges (Miller, 1978). Troncale identified 100 system isomorphisms as a foundation for categorizing and applying system knowledge in processes (Troncale, 2006). These theories have made significant contributions to revealing systemic commonalities, but they primarily focus on universal laws among systems rather than investigating similarity itself as an independent object of study to explore its specific effects on complex systems and collaborative processes. Thus, in contrast to traditional approaches that emphasize system universals, this research adopts a perspective centered on similarity, examining its role in system evolution and collaboration. This approach represents a fundamental departure in both theoretical orientation and research focus.

Similarity is inherently a relative concept. It does not imply complete identity but rather the presence of certain shared attributes amid differences (Tversky, 1977). Existing studies predominantly emphasize the impacts of high similarity (i.e., commonalities or homogeneity), mainly exploring how such similarity fosters convergence and its underlying mechanisms. However, there has been relatively little research on low similarity (i.e., differences or heterogeneity), particularly regarding how to balance homogeneity and heterogeneity during system evolution and collaboration. Yet in reality, system survival and evolution depend not only on commonalities but also on differences. Commonalities provide systems with the basic functions to maintain themselves in their environment, while differences grant them the capacity to adapt and compete. For instance, in ecosystems, different species may compete for the same ecological niche, but through adaptive divergence, they evolve distinct survival strategies, thereby reducing direct competition and maintaining ecosystem stability (Macarthur & Levins, 1967). In corporate systems, multinational companies often adopt localization strategies in different markets: although their core business models remain similar, they pursue differentiation strategies to enhance market adaptability (Porter, 2008). These examples underscore the critical importance of the dynamic balance between homogeneity and heterogeneity for sustainable system development. Delving into this balancing mechanism can enhance our understanding of complex system evolution and inform better management of such systems.

Grounded in GST and Complex Adaptive Systems Theory (CAST), this paper proposes the High-Low Similarity Component Model (HLSCM), which takes similarity as a core variable to explore its role in complex systems and collaborative processes. This model posits that a system can be divided based on the degree of similarity into a High-Similarity Component (HSC) and a Low-Similarity Component (LSC). The former provides stability and order, while the latter endows the system with adaptability and innovative capacity. The interplay between HSC and LSC determines the system's overall dynamic equilibrium, thereby influencing the efficiency and performance of system collaboration. This theoretical framework not only explains the multifaceted influences of similarity in different types of systems (i.e., business alliances, technology ecosystems, and human-machine collaboration systems), but also offers theoretical guidance for management practices.

This research integrates the concepts of similarity and difference to examine the structural and behavioral dynamics of complex systems. The central objective is to develop a systemic theoretical framework that explains how similarity shapes system interaction, evolution, and collaboration, and how complex systems can dynamically balance homogeneity and heterogeneity to achieve collaborative optimization. To achieve this, the study proposes the HLSCM, which conceptualizes similarity as having both integrative and differentiating functions in system operations. First, drawing on GST and CAST, the HLSCM provides a novel analytical lens that systematically incorporates both homogeneity and heterogeneity within and between systems. Second, the model distinguishes the core properties of HSC and LSC to explain how they jointly shape system function and behavior. The HSC is characterized by stability, compatibility, and universality, which contribute to systemic order and coherence. In contrast, the LSC

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exhibits agility, adaptability, and uniqueness, enabling responsiveness and innovation. Third, the study emphasizes the co-evolutional relationship between similarity and interaction relationships: similarity not only influences the initial patterns of interaction but is also recursively shaped by the outcomes of these interactions, thereby forming a dynamic similarity feedback loop. Finally, the study introduces three dynamic balancing principles to illustrate how systems pursue an evolving equilibrium between HSC and LSC, thereby achieving a balance between homogeneity and heterogeneity. Altogether, this research offers a similarity-based framework for systemic analysis, helping scholars and practitioners identify critical similarity components, optimize similarity configurations, and manage collaborative tensions to achieve optimal similarity in complex, dynamic environments.

2 | Theoretical Background and Conceptual Definitions

2.1 | Theoretical Background

The theoretical foundation of this study primarily draws from GST and CAST. GST posits that all systems share universal structural principles at varying levels, providing a foundational perspective for identifying similarities across systems (Bertalanffy, 1968). However, prior research has often treated similarity, such as isomorphism or functional equivalence, as a static trait. In contrast, this study reconceptualizes similarity as a dynamic and evolving relational feature that plays a central role in shaping system interactions, coordination patterns, and collaborative adaptability. This view adds a dynamic emphasis to the traditional GST perspective, highlighting how systems balance homogeneity and heterogeneity to sustain coherence, adaptability, and collaborative effectiveness in evolving environments.

Meanwhile, CAST emphasizes that systems consist of interacting agents whose local actions give rise to self-organization and adaptive evolution (Holland, 1992, 1996). The HLSCM developed in this study reflects this logic: it captures how systems dynamically adjust the proportion and interaction between HSC and LSC in response to internal requirements and environmental complexity. When the HSC becomes overly dominant, divergence strategies are activated to reinforce the distinctiveness of individual actors, preventing rigid homogeneity. Conversely, when the LSC expands too rapidly, causing fragmentation and rising communication costs, convergence strategies are strengthened to enhance overall system coordination and stability, avoiding severe heterogeneity. The system's ability to modulate this ratio through feedback and adaptation embodies the essence of CAST, where micro-level changes drive macro-level structural evolution.

Together, the HLSCM integrates GST's structural perspective, which emphasizes systemic composition and cross-system commonalities, with CAST's adaptive logic, which accounts for how interaction dynamics and environmental feedback shape system evolution. This integrated foundation enables a more nuanced understanding of how complex systems achieve sustainable collaboration through the dynamic balance of similarity and difference.

2.2 | Similarity

Similarity is defined as the comparative relationship attribute where two or more entities exhibit a certain degree of likeness in specific aspects (attributes or laws) (Xu, Deng, Wu, & Huo, 2024). GST highlights two primary types of similarity: isomorphism and functional equivalence (Bertalanffy, 1968). Isomorphism refers to structural consistency among systems, whereas functional equivalence refers to the similarity in their functions. Even if systems differ structurally, they can still achieve highly similar functional outcomes. GST suggests that systems in different domains, though diverse in their manifestations, often adhere to similar organizational principles and dynamic laws (Bertalanffy, 1968). Thus, similarity and difference (or low similarity) form the basis for classifying and understanding systems and for shaping interaction patterns that impact system adaptability and evolutionary pathways. From the perspective of complex systems, similarity encompasses the consistency of subsystems in terms of particular attributes or patterns, such as structural, functional, or goal similarity. Additionally, when multiple systems collaborate, they can collectively be viewed as a collaborative system that exhibits complex system characteristics. Here,

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similarity emerges through shared attributes or patterns across collaborative actors, while difference refers to attributes or patterns unique to a particular system that are not universally shared across all systems.

2.3 | Similarity Relationships and Interaction Relationships

A similarity relationship is a comparative relationship that captures both the commonalities and differences between two or more entities in specific attributes or patterns (Tversky, 1977). This relationship can be static (relatively stable) or dynamic (changing over time or with environmental conditions). At its core, a similarity relationship reflects the underlying similarity among entities, serving as an associative form induced by similarity itself. In contrast, an interaction relationship refers to the mutual influence and connections between entities, elements, or systems that arise through the exchange of energy, information, or material (Bertalanffy, 1968). In complex systems, interaction relationships typically manifest as mutual interactions. Such interactions embody the identity of cause and effect: the actions of one system not only affect external systems but also have reciprocal effects on itself (Hegel, 2014).

3 | Model Construction and Mechanism Analysis

3.1 | Basic Model and Formulae

According to the HLSCM, a system can be decomposed into HSC and LSC based on the degree of similarity between elements. These two components perform distinct functions and interact with each other, shaping the system's complexity and functionality. Rather than focusing on general interaction relationships, this study constructs the system model from the perspective of similarity relationships. For conceptual clarity, the following mathematical model is developed based on a complex collaborative system consisting of two functionally interconnected subsystems. This two-subsystem configuration serves as a foundational case, and the modeling approach can be readily generalized to systems comprising multiple subsystems (multiple collaborative entities).

Similarity Measures between Elements of Systems. Let complex collaborative system S be composed of two subsystems (A and B), each containing a set of elements: $A = \{a_1, a_2, \dots, a_i\}$, $B = \{b_1, b_2, \dots, b_j\}$. The measurement of similarity between elements draws on the feature-based similarity theory proposed by Tversky (Tversky, 1977), which emphasizes that objects can be described by sets of attributes representing their features. According to this view, the similarity between two objects can be assessed by comparing their respective attribute sets. For any two elements $a_i \in A$ and $b_j \in B$, their similarity is evaluated across four dimensional features: structural (s), functional (f), behavioral (b), and evolutionary (e). For a given dimension $\mu = \{s, f, b, e\}$, let $C_\mu(a_i)$ and $C_\mu(b_j)$ denote the sets of attributes (a or features associated with a_i and b_j , respectively, in dimensional feature μ . These features may include shared or unique attributes. Shared attributes are those that exist in both elements, while unique attributes are specific to one element only. The feature composition of a pair of elements can thus be expressed as Equation (1).

$$C(a_i, b_j) = \begin{cases} C_{\text{same}}(a_i, b_j) = C_\mu(a_i) \cap C_\mu(b_j) \\ C_{\text{diff}}(a_i, b_j) = \{C_\mu(a_i) - C_\mu(b_j), C_\mu(b_j) - C_\mu(a_i)\} \end{cases} \quad (1)$$

Specifically, $C_\mu(a_i) \cap C_\mu(b_j)$ denotes the shared features of elements a_i and b_j ; $C_\mu(a_i) - C_\mu(b_j)$ represents the features that belong to a_i but not to b_j ; and $C_\mu(b_j) - C_\mu(a_i)$ refers to the features that belong to b_j but not to a_i .

The feature-level similarity $Sim_\mu(a_i, b_j)$ is calculated using the Jaccard similarity coefficient (Bag, Kumar, & Tiwari, 2019), as shown in Equation (2).

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$$Sim_{\mu}(a_i, b_j) = \frac{|C_{\mu}(a_i) \cap C_{\mu}(b_j)|}{|C_{\mu}(a_i) \cup C_{\mu}(b_j)|} \quad (2)$$

Specifically, $C_{\mu}(a_i) \cap C_{\mu}(b_j)$ denotes the shared features of elements a_i and b_j ; $C_{\mu}(a_i) \cup C_{\mu}(b_j)$ denotes all features of elements a_i and b_j .

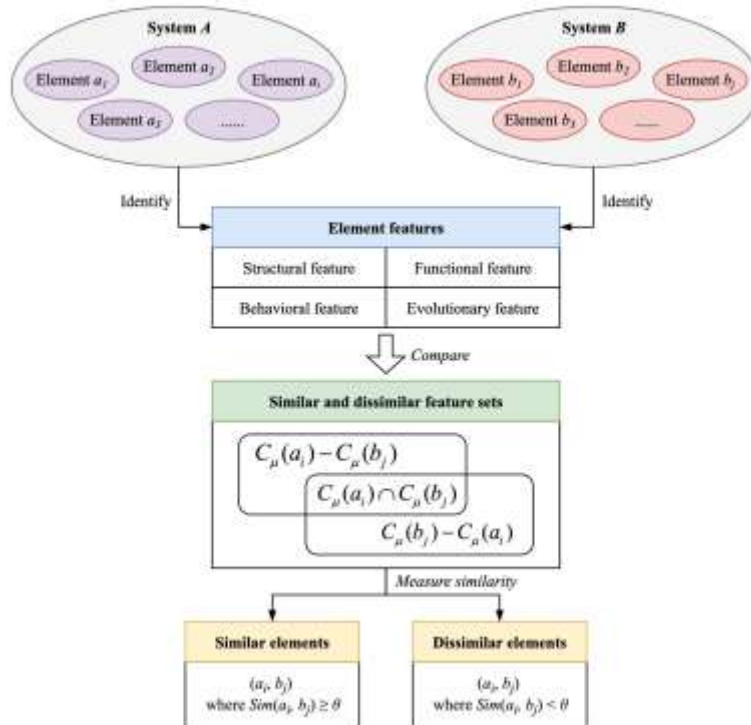
This metric quantifies the degree of overlap between the two feature sets in dimensional feature μ , ranging from 0 (completely dissimilar) to 1 (identical). Thus, the overall element-level similarity is defined as a weighted sum, as shown in Equation (3). Dimension weights can be set through expert judgment, the analytic hierarchy process, or data-driven methods to reflect the relative importance of each similarity dimension in specific application scenarios.

$$Sim(a_i, b_j) = \sum_{\mu \in \{s, f, b, e\}} w_{\mu} \cdot Sim_{\mu}(a_i, b_j) \quad (3)$$

where $w_{\mu} \in [0,1]$ and $\sum w_{\mu} = 1$ denote the relative importance of each dimension.

HSC and LSC Classification Rules. Based on a predefined similarity threshold θ , elements within the system are classified into similar and dissimilar elements. The threshold θ can be empirically determined or theoretically set based on domain-specific similarity requirements. An element from system A is classified into the HSC if there exists at least one element in system B with which it shares a similarity exceeding the predefined threshold θ . Conversely, if no such element exists in system B , the element is considered part of the LSC. As shown in Exhibit 1, the method identifies similar and dissimilar elements between systems based on a predefined similarity threshold.

Exhibit 1. Similar and dissimilar elements identification method between systems



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Thus, system A and B can be deconstructed into two interrelated components: HSC and LSC, as shown in Equation (4) and (5). This represents a dialectical integration of holism and reductionism, enabling both the decomposition of a system into interpretable parts and the recognition of its overall structure.

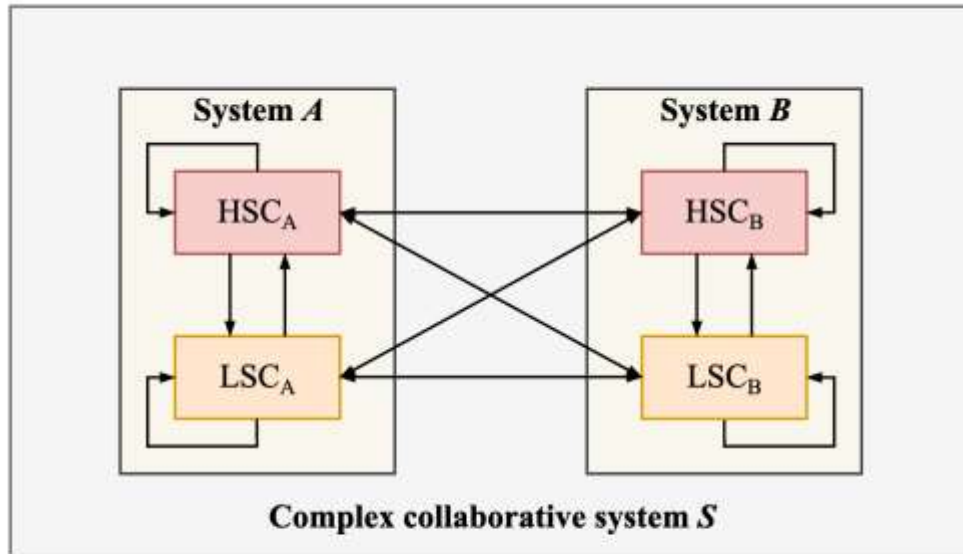
$$A = \begin{cases} HSC_A = \{a_i \in A \mid \exists b_j \in B, Sim(a_i, b_j) \geq \theta\} \\ LSC_A = \{a_i \in A \mid \forall b_j \in B, Sim(a_i, b_j) < \theta\} \\ A = HSC_A \cup LSC_A, \quad HSC_A \cap LSC_A = \emptyset \end{cases} \quad (4)$$

$$B = \begin{cases} HSC_B = \{b_j \in B \mid \exists a_i \in A, Sim(b_j, a_i) \geq \theta\} \\ LSC_B = \{b_j \in B \mid \forall a_i \in A, Sim(b_j, a_i) < \theta\} \\ B = HSC_B \cup LSC_B, \quad HSC_B \cap LSC_B = \emptyset \end{cases} \quad (5)$$

Specifically, HSC_A and LSC_A represent the high-similarity and low-similarity components of system A , respectively, while HSC_B and LSC_B represent those of system B .

Conceptual Framework of the HLSCM. To enhance understanding, Exhibit 2 presents the conceptual framework of the HLSCM, illustrating the decomposition of systems into HSC and LSC, as well as the interaction paths between and within systems. Accordingly, system interactions can be analyzed across three primary channels: HSC–HSC interactions (between similar elements), LSC–LSC interactions (between dissimilar elements), and HSC–LSC interactions (cross-domain interactions between similarity and difference). This layered interaction model reflects the internal coordination and external adaptability of complex systems. Such a formulation provides a powerful framework for analyzing the structural dynamics and collaborative behavior of complex systems. It allows researchers to distinguish core stable mechanisms (embodied by the HSC) from adaptive or innovative features (represented by the LSC), and to examine how similarity and difference jointly shape system-level outcomes.

Exhibit 2. Conceptual framework of the HLSCM



Note: From the perspective of system A or B

External interactions HSC = High-similarity component
 Internal interactions LSC = Low-similarity component

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3.2 | Properties of the HSC and LSC

To better understand the structural dynamics of complex systems, it is essential to recognize that the HSC and LSC reflect not the properties of individual elements, but the aggregated, system-level characteristics emerging from similarity relationships. This classification provides a systemic perspective that integrates both reductionist and holistic views, enabling an in-depth exploration of the distinctive functions and roles that HSC and LSC play within and across systems.

Properties of the HSC. The HSC is characterized by three key properties: stability, compatibility, and universality. Stability is one of the fundamental properties of the HSC, referring to its capacity to maintain essential functions and structures despite changes in the external environment. This stability ensures that the system can continue to operate under uncertain conditions, reducing the risk of collapse from external disturbances. In social systems, for instance, core legal principles are universally applicable across countries, thus ensuring continuity of social order (Pech, 2022). In biological systems, the stability of genetic mechanisms ensures that organisms maintain essential physiological functions across generations, even if environmental factors affect gene expression. DNA replication and protein synthesis remain highly stable (Kitano, 2004). This stability makes the HSC the backbone of the system, providing a stable environment for the LSC and ensuring sustained system evolution in complex environments.

Compatibility describes the HSC's adaptability within the system and across systems, enabling efficient coordination of diverse elements. The compatibility of the HSC is often expressed through standardization, modularity, or universal design, which enhances interoperability. In technological systems, universal communication protocols (such as TCP/IP) ensure that different devices can connect and communicate regardless of their hardware or software architectures (Al-Fuqaha, Guizani, Mohammadi, Aledhari, & Ayyash, 2015). In business management systems, global supply chains rely on standardized production and management systems (like ISO quality management standards), enabling different enterprises and countries to collaborate within a shared framework (Curkovic & Sroufe, 2011). The HSC's compatibility enhances both internal collaboration and cross-system collaboration, enabling resource sharing and reducing integration costs.

Universality reflects the applicability of HSC elements across different systems, implying that these elements maintain similar characteristics and functions regardless of the field or scale. This universality allows the HSC to serve as a common foundation across systems, improving predictability and analytical capabilities. In the natural sciences, thermodynamic laws are a typical example of universality, applying to both macro-scale physical systems (like galaxy evolution) and micro-scale systems (like molecular motion), providing a consistent theoretical framework for analysis. In computer science, the core ideas of basic algorithms (such as sorting and searching) are universal across different programming languages and hardware architectures. Although the specific implementation may vary from environment to environment, this universality ensures the wide applicability of computer systems and lays the foundation for technical standardization (Cormen, Leiserson, Rivest, & Stein, 2022). The universality of the HSC facilitates the generalization of system theories beyond individual cases.

Together, these three key properties define the HSC. Stability ensures that the system maintains its core functions in changing environments, compatibility facilitates efficient cooperation within and across systems, and universality allows for the general application of these stable elements across various systems.

Properties of the LSC. The LSC has three key properties: agility, adaptability, and uniqueness. Agility refers to the ability of LSC elements to rapidly respond to environmental changes and dynamically adjust to ensure effective system operation. In complex systems, agility means that these less similar components can quickly reorganize, reconfigure, or innovate to address external pressures or new demands. In enterprises, for example, Overby et al. proposed that design, production, and logistics teams adopt modular collaboration and share data platforms (such as SAP integrated systems) to allow rapid reconfiguration of resources in order to improve enterprise agility (Overby, Bharadwaj, & Sambamurthy, 2006). In biological systems, genetic diversity allows certain individuals or species to adapt rapidly to environmental changes,

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such as the evolution of antibiotic resistance in bacterial populations (Lenski & Travisano, 1994). Agility ensures that the LSC provides the system with short-term responsiveness and flexibility.

Adaptability refers to the LSC's capacity for long-term optimization, evolution, and self-adjustment, enabling the system to survive and remain competitive in different environments. Unlike agility, which emphasizes short-term responses, adaptability involves ongoing evolution and adjustment (Holland, 1996). In ecosystems, competition for survival and niche differentiation reflects this adaptability. For instance, while wolves and foxes both belong to the order Carnivora, they have developed distinct survival strategies and hunting behaviors suited to their environments (Schoener, 1974). In social systems, the diversity of governance models, legal frameworks, and cultural institutions reflects the adaptability of LSC elements, allowing societies to form unique organizational structures based on historical and developmental contexts (Soskice, 2001). Adaptability ensures that LSC elements can continuously optimize themselves in evolving environments, enhancing the system's long-term resilience.

Uniqueness means that LSC elements possess distinctive, irreplaceable characteristics, giving the system a unique advantage in a competitive and diverse environment. Uniqueness allows the LSC to provide the system with personalized features that strengthen competitiveness and foster innovation. According to Barney's resource-based view, a firm's core competitiveness stems from its unique resources and capabilities, which are irreplaceable and heterogeneous, thus forming a sustainable competitive advantage (Barney, 1991). In biological systems, Tilman found that functional uniqueness among species increases the adaptability and resource efficiency of ecosystems, thereby boosting the competitiveness of the entire system (Tilman, 1999). Uniqueness ensures that the LSC contributes to the system's diversity, enabling innovation and multidimensional development.

In summary, the agility of the LSC provides rapid responses to short-term changes, adaptability supports long-term evolutionary optimization, and uniqueness gives the system a competitive edge and innovative potential. These properties define the core role of the LSC in complex systems, making it a driver of system evolution, competition, and innovation.

3.3 | Co-Evolution of Similarity and Interaction Relationships

The Influence of Similarity Relationships on Interaction relationships. Similarity relationships exert a foundational influence on the formation, intensity, and direction of interaction relationships within complex systems. When subsystems or actors perceive a high degree of similarity, whether in structure, function, values, or behavior, they are more likely to develop mutual trust, shared expectations, and communication efficiency, thereby facilitating cooperative interactions (Ertug et al., 2022). HSC contribute to system coherence by promoting alignment and interoperability, which lowers coordination costs and enhances the likelihood of stable, long-term collaborations. For instance, in organizational management, Lane and Lubatkin's concept of relative absorptive capacity posits that inter-firm knowledge transfer is most effective when partner firms share similarities in their knowledge bases, organizational structures, and dominant logics, thereby facilitating technological collaboration (Lane & Lubatkin, 1998). However, when similarity reaches an excessively high level, systems may shift toward competition due to overlapping resources and objectives. Resource-based theory suggests that firms with similar resource endowments and market positions tend to perceive each other as direct competitors, leading to competitive tension (Barney, 1991; Chen, 1996). Likewise, the ecological principle of competitive exclusion posits that two species with identical ecological niches cannot stably coexist under resource limitation, resulting in competitive displacement (Gauze, 1934). Conversely, LSC, while potentially inhibiting initial interaction due to cognitive or operational distance, may stimulate complementary exchanges, innovation, or adaptive learning when properly integrated. For example, in organizational cooperation, teams with significant cultural differences may experience reduced collaboration efficiency and performance due to conflict and barriers to social integration (Stahl, Maznevski, Voigt, & Jonsen, 2010). Thus, similarity relationships affect interaction relationships by influencing cognitive costs, trust levels, and resource diversity. This influence typically follows an inverted U-shaped curve: moderate similarity proves most conducive to strengthening interactions, whereas extremely high or low similarity tends to dampen functional engagement. By

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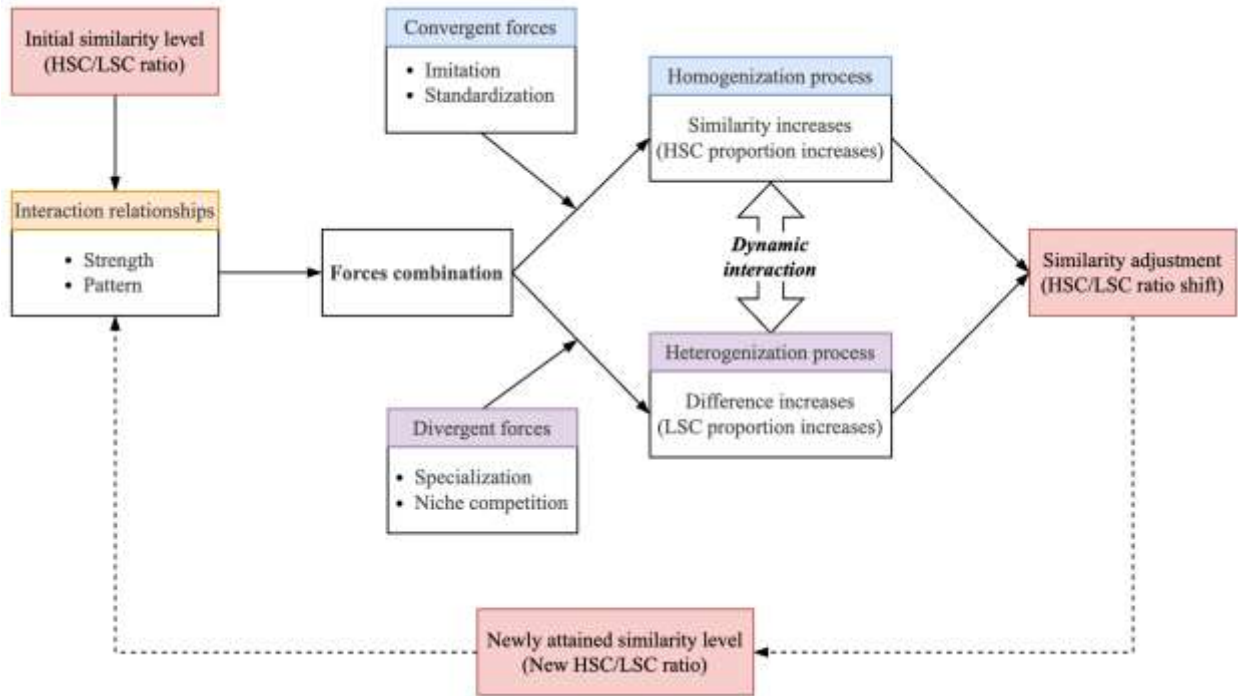
recognizing and managing the degrees and dimensions of similarity, systems can better orchestrate interaction patterns that balance integration with diversity, coherence with adaptability.

The Influence of Interaction Relationships on Similarity Relationships. Interaction relationships not only reflect the direct interactions between systems but also gradually shape similarity levels through long-term engagement. Cooperative relationships tend to enhance similarity because they promote the sharing of resources, knowledge, and information, leading to convergence over time. For example, interorganizational collaboration often leads to increased similarity between partner firms through processes of mimetic isomorphism and knowledge assimilation (DiMaggio & Powell, 1983; Gulati, Sytch, & Tatarynowicz, 2012). Conversely, competitive relationships may prompt systems to maintain or even accentuate their differences to avoid direct confrontation or to establish unique positions within their environments. In business competition, for example, firms frequently pursue differentiation strategies to avoid homogeneity, thereby preserving distinctiveness in product offerings, brand identity, and market positioning (Su, Gao, & Tan, 2024). The principle of competitive exclusion in ecology further demonstrates that species engaged in prolonged competition will either develop different ecological niches or face elimination (Gauze, 1934). Hence, interaction relationships shape similarity relationships by reinforcing convergence through cooperation and encouraging divergence through competition, thereby guiding systems along specific evolutionary trajectories.

The Co-Evolutionary Mechanism: Similarity Feedback Loop. Similarity and interaction are not unidirectional or static constructs, but rather dynamically co-constructed through a mechanism known as the similarity feedback loop. As shown in Exhibit 3, the process begins with an initial similarity level between systems, characterized by a specific ratio of HSC and LSC. This initial configuration shapes the strength and pattern of interaction relationships. Under the influence of the external environment, systems are subject to both convergent forces (e.g., imitation, standardization) and divergent forces (e.g., specialization, niche competition), which exert simultaneous pressures on the system. In response, systems engage in adaptive modulation, adjusting the composition of HSC and LSC to maintain functional viability. Specifically, these opposing forces trigger either homogenization or heterogenization processes. Homogenization increases the proportion of HSC, enhancing compatibility and system coherence; heterogenization increases the proportion of LSC, fostering differentiation and adaptive uniqueness. These processes occur in a state of dynamic interaction, continually shifting the internal balance between homogeneity and heterogeneity. The resulting changes in HSC/LSC ratios constitute a new similarity level, which in turn influences subsequent interaction relationships, thereby completing the feedback loop. Importantly, this loop is not merely cyclical but regulatory, enabling systems to dynamically adjust their internal configurations to meet evolving demands. The similarity feedback loop thus represents a fundamental mechanism for balancing stability and adaptability, facilitating long-term co-evolution and strategic alignment in complex collaborative systems.

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Exhibit 3. Similarity feedback loop



3.4 | Dynamic Balance between HSC and LSC

The HSC and LSC of a system are not static entities; rather, they are dynamically adjusted throughout the system's evolutionary process to maintain overall stability and adaptability. Dynamic balance refers to the relatively stable proportion between HSC and LSC during system operation, enabling the system to simultaneously leverage the stability, compatibility, and universality of the HSC for stable functioning, and the agility, adaptability, and uniqueness of the LSC to respond to environmental changes. An excessive expansion of the HSC may result in excessive homogenization, diminishing innovation capacity and environmental adaptability. Conversely, an overrepresentation of the LSC may lead to excessive heterogenization, exacerbating internal incompatibility and compromising collaborative efficiency. Fundamentally, the dynamic balance between HSC and LSC represents a process of adaptive alignment between interaction relationships and similarity relationships. During system evolution, the internal similarity structure, specifically the proportion between HSC and LSC, must be continuously adjusted to meet both external environmental demands and internal interaction requirements. Therefore, understanding the mechanisms underlying the dynamic balance between HSC and LSC is crucial for revealing the laws of system evolution and optimizing managerial decision-making.

The dynamic balance between the HSC and LSC constitutes a core mechanism for ensuring a system's long-term stability and adaptability. This dynamic equilibrium is governed by three interrelated principles: the functional coordination principle, the adaptive modulation principle, and the tensional balance principle: (1) The functional coordination principle posits that the HSC and LSC must form a functionally complementary and synergistic relationship within the system. While the HSC provides the foundation for stability and collaborative efficiency, the LSC is responsible for driving innovation, variation, and environmental responsiveness; (2) The adaptive modulation principle emphasizes that the system should dynamically adjust the proportional relationship between HSC and LSC in response to the complexity of its external environment. In more stable environments, the dominant role of the HSC becomes increasingly important; conversely, in more dynamic environments, the agility and adaptability of the LSC are critical for the system's responsiveness and resilience; and (3) The tensional balance principle

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reveals the mutually constraining relationship between HSC and LSC. The similarity inherent in the HSC generates systemic cohesion, whereas the heterogeneity of the LSC drives evolutionary change. The tension between the two must be maintained within a dynamically adjustable range; otherwise, the system risks becoming either overly rigid or excessively chaotic. Together, these principles define how systems maintain a stable yet flexible dynamic balance between HSC and LSC under evolving environmental conditions.

4 | Discussion

4.1 | Theoretical Implications

This study offers several important theoretical contributions to the understanding of system similarity and its role in complex systems and system collaboration. This study introduces the HLSCM to conceptualize and distinguish HSC and LSC within and across complex systems. Unlike prior models that predominantly assume uniformity or treat similarity as a single-dimensional construct (McPherson, Smith-Lovin, & Cook, 2001; Melamed et al., 2020), HLSCM captures the multi-layered nature of system composition by integrating both homogeneous and heterogeneous structures. This dual-structure perspective advances the understanding of internal system diversity and dynamic structural evolution in collaborative settings, especially under conditions of complexity and uncertainty. Thus, the HLSCM as a systemic analysis framework enriches the theoretical toolkit for understanding how complex systems balance homogeneity and heterogeneity to achieve both stability and adaptability in dynamic collaborative environments.

This research introduces the similarity feedback loop as a co-evolutionary mechanism between similarity relationships and interaction relationships. Prior studies have often regarded similarity as a static precondition for interaction or as a predictor of dyadic outcomes (Ertug et al., 2022). By contrast, this study conceptualizes similarity and interaction as mutually constitutive and dynamically co-evolving constructs. This co-evolutionary mechanism highlights the recursive nature of systemic relationships, whereby similarity is both shaped by and shapes ongoing system interactions. This view extends static models by incorporating temporal and reciprocal effects, offering a more nuanced explanation for how convergence and divergence emerge and evolve in complex systems.

The study puts forward a dynamic balancing mechanism between HSC and LSC, grounded in three theoretical principles: functional coordination, adaptive modulation, and tensional balance. This mechanism captures the internal tensions and adaptive logics that govern the evolution of complex systems. This mechanism addresses how systems negotiate homogeneity and heterogeneity over time to achieve both stability and flexibility. Unlike static models of fit or contingency (Lawrence, 1986), the HSC–LSC balancing mechanism reflects a dynamic, non-linear process of organizational evolution and offers a novel lens for understanding how systems sustain coherence while adapting to environmental complexity. While HSC contributes to stability, cohesion, and coordination efficiency, LSC introduces diversity, innovation potential, and environmental adaptability. The proposed mechanism suggests that effective system evolution depends on neither full convergence nor radical differentiation, but rather on the capacity to orchestrate functional coordination across HSC, modulate the adaptability of LSC, and maintain a productive tension between the two. These insights have the potential to stimulate new theoretical developments in GST, strategic management, and organization science.

4.2 | Practical Implications

The HLSCM and its associated mechanisms have practical significance for system and organizational design, innovation strategy, and cross-system collaboration. The distinction between HSC and LSC offers managers a structural lens for diagnosing and reconfiguring internal system components. In organizational contexts, the HSC may correspond to core routines, values, or standardized practices, while the LSC may reflect experimental units, creative teams, or external partnerships. Managers can improve system responsiveness and innovation by maintaining a strategic balance between the two, ensuring the HSC secures efficiency and coordination, while the LSC enables exploration and differentiation.

For system designers and organizational managers, the integrated application of the similarity feedback loop and the dynamic balance mechanism offers a strategic framework for diagnosing, regulating,

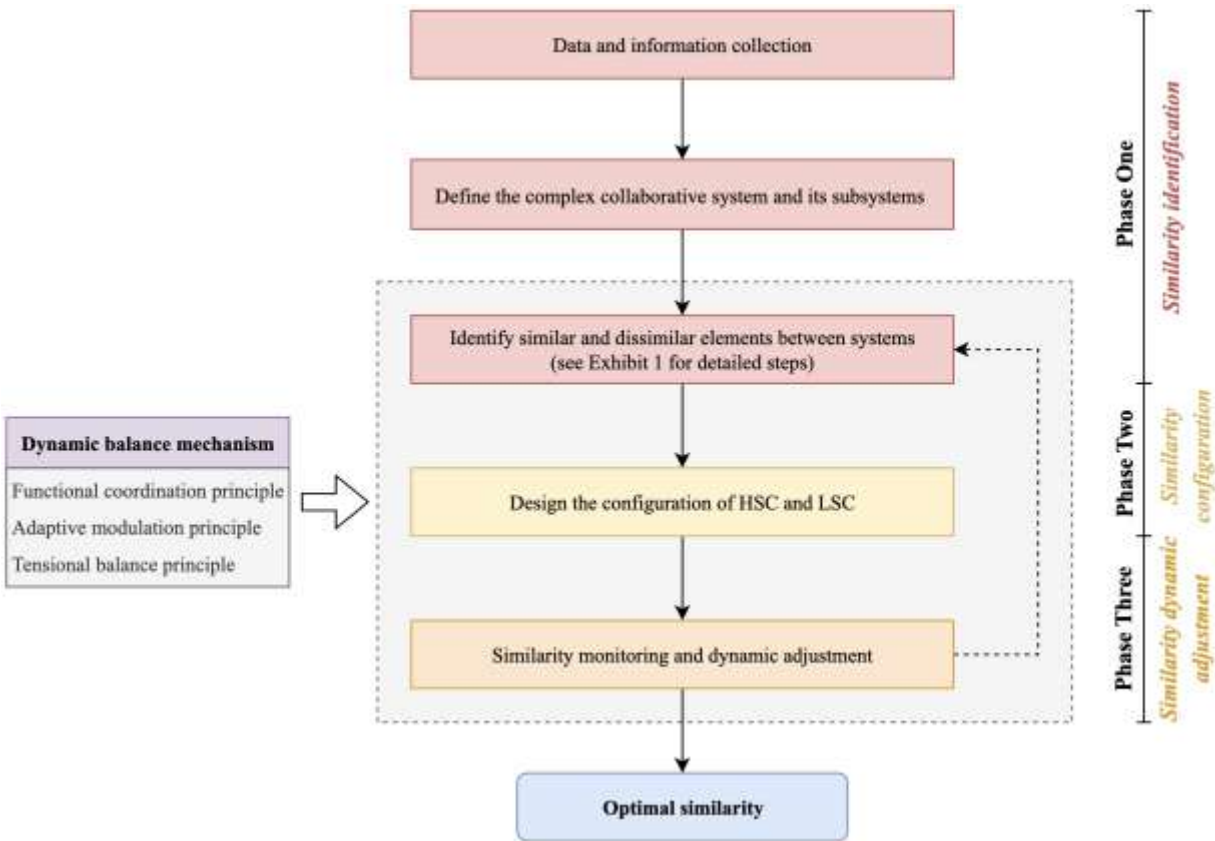
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and optimizing system configuration—thereby enhancing collaborative efficiency, innovation capacity, and overall adaptability. By monitoring the HSC/LSC ratio and recognizing the impact of external pressures, such as imitation imperatives or market differentiation demands, leaders can proactively adjust system configurations. This enables them to maintain an optimal similarity level that balances coherence and flexibility. For example, in relatively stable industries (e.g., utilities, infrastructure), a larger HSC footprint may be desirable for maintaining predictability and compliance. In contrast, in volatile sectors (e.g., tech, aerospace, creative industries), organizations may benefit from expanding their LSC to enable faster adaptation. Managers should assess the balance between HSC and LSC not as a static trade-off, but as a dynamic parameter that can be adjusted in response to environmental turbulence, lifecycle stage, or strategic objectives. Analysis of the dynamic balance mechanism suggests that effective system governance depends on three interrelated principles: functional coordination between HSC and LSC, adaptive modulation of their proportional balance, and the maintenance of tensional equilibrium to avoid organizational rigidity or fragmentation. The model guides continuous alignment between internal system composition and external demands, supporting long-term sustainability and collaborative effectiveness.

In practical applications, the HLSCM outlines a systematic operational path (similarity management process) for managing system and enhancing collaboration. This framework comprises three key steps: similarity identification, similarity configuration, and similarity dynamic adjustment, which collectively aim to achieve optimal similarity (see Exhibit 4). First, managers should identify the HSC and LSC within the system, recognizing which structures, processes, or elements represent commonality, stability, and compatibility, and which reflect differentiation, uniqueness, and adaptive potential. Second, based on this identification, structural configuration should be performed: intentionally designing systems with strong HSC foundations (such as shared protocols, unified information infrastructures, and collective visions), while preserving flexible space for LSC-driven local experimentation, innovation, and diversity. Third, a dynamic adjustment mechanism must be established to monitor the HSC–LSC ratio continuously, adapting the structure in response to changes in external environments (e.g., increasing uncertainty or market volatility) and internal performance (e.g., collaboration efficiency or innovation output). For example, in cross-functional project management, a centralized coordination platform (HSC) can ensure information consistency, while individual departments (LSC) retain autonomy for experimentation and response strategies. This process is facilitated through regular feedback and performance evaluation, which together contribute to systemic optimization.

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Exhibit 4 Similarity management process



4.3 | Future Research Directions

This study suggests several potential directions for future research. First, future empirical studies can operationalize the HSC and LSC constructs across different domains, such as interorganizational alliances, innovation ecosystems, or socio-technical systems. Quantitative techniques like configurational analysis (e.g., fsQCA), structural modeling, or network analysis may help validate the effects of HSC–LSC configurations on system performance, resilience, and adaptability.

Second, the similarity feedback loop can be further explored through longitudinal or simulation-based research. Agent-based models or system dynamics modeling could be used to simulate how systems evolve under varying similarity thresholds, interaction intensities, or environmental volatilities. These dynamic modeling efforts may uncover tipping points, lock-in effects, or co-evolutionary patterns that enrich our understanding of similarity feedback.

Third, future research may delve deeper into the multi-level dynamics between similarity and interaction relationships. For instance, individual-level similarity (e.g., shared values among team members) may aggregate into group-level HSC, while inter-group divergence may constitute LSC at the organizational level. Exploring how similarity operates and transforms across levels (individual, team, organizational, and network) would offer valuable insights into coordination, differentiation, and performance trade-offs.

Finally, extending the HLSCM framework to digital, intelligent, or AI-augmented systems is another promising direction. In human–AI collaborative settings, for example, similarity in task logic, learning models, or communicative behaviors may influence human trust and system efficiency. Exploring how artificial agents acquire, maintain, or strategically vary similarity with human counterparts may open up new theoretical territory in human–AI interaction and socio-technical system design.

5 | Conclusion

Grounded in GST and CAST, this study proposes the HLSCM to explain how similarity and difference interact and jointly influence the stability and adaptability of complex systems. This model decomposes a system into HSC and LSC, where the former contributes to system stability and order, while the latter enables adaptability and innovation. Through this framework, we explore the co-evolution of similarity and interaction relationships, and further reveal the dynamic balance mechanism between the HSC and LSC within complex systems, revealing how systems navigate between homogeneity and heterogeneity to remain both stable and adaptive. Thus, this study provides a similarity-based systemic analysis framework (HLSCM and its associated mechanisms) that enables scholars and practitioners to identify critical similarity components, optimize similarity configurations, track their evolution, and manage collaborative tensions in complex, dynamic environments. Together, this study contributes to systems theory by offering a dynamic and interactional view of similarity, with implications for designing adaptive, collaborative, and resilient systems.

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