Reintegrating Classification into the Concept of Analogy

Liying Zhang
University of Chinese Academy of Sciences
Institute of Philosophy, Chinese Academy of Sciences
zhangliying@ucas.ac.cn

Abstract

This paper argues that while the Western tradition of analogy has largely emphasized comparison, analogy fundamentally entails both classification and comparison. Through a progressive analysis, we demonstrate that analogy and metaphor can both be understood as forms of structured comparison. However, analogy operates through intra-categorical comparison, whereas metaphor identifies similarities across different categories, representing a more focused mode of comparative reasoning. Finally, the paper examines structured analogies incorporating both classification and comparison, and explores their potential applications and implications for the development of artificial intelligence.

Introduction

Analogy is a fundamental component of human cognition and serves as a key mechanism for knowledge transfer and innovation. Beyond its role in everyday reasoning, analogy is widely utilized in scientific research. Bartha (2024) has documented numerous instances of analogical reasoning across disciplines such as fluid mechanics, astronomy, biology, anthropology, archaeology, acoustics, pharmacology, and electrostatics. In the field of artificial intelligence, analogy is also a commonly employed method and is regarded as a crucial element of imaginative intelligence.

Mathematical mappings can likewise be understood as forms of analogy. When children begin to learn the concept of numbers, they often abstract numerical information from concrete objects, establishing a mapping between numbers and sets of objects—a process that inherently involves analogical thinking. Similarly, disciplines such as bionics rely heavily on analogical reasoning. In fact, notions such as association, correspondence, mathematical and morphological homology, isomorphism, similarity, and metaphor are all closely related to analogy.

Nevertheless, explaining the nature of analogy remains a challenging problem in the fields of logic and artificial intelligence. What precisely constitutes an analogy? How should analogies be evaluated? What is the relationship between analogy and metaphor? This paper aims to explore the cognitive principles of analogy in a more open and fundamental manner.

This paper will first provide a concise review of analogy theory, highlighting that contemporary Western theoretical approaches predominantly emphasize comparison and similarity relations. It argues, however, that a complete conception of analogy should incorporate both classification and comparison. Introducing a classificatory component not only aligns with cognitive reality but also aids in clearly distinguishing analogy from metaphor. Subsequently, the paper analyzes the structural foundations of classification and comparison, as well as their structured integration. Finally, it discusses the potential implications of incorporating classification into analogy theory for the development of artificial intelligence.

A Review of Reasearch on Aanlogy

1. Analogies from the Western Tradition Focus on Comparison

According to the Stanford Encyclopedia of Philosophy entry on analogy and analogical reasoning (Bartha 2024), "Analogy is a **comparison** between two objects or sets of objects, focusing on the aspects in which they are deemed **simila**r." This definition highlights two key concepts: comparison and similarity. The same source (Bartha 2024) summarizes general textbook-style guidelines for evaluating analogical arguments, as proposed by logicians and philosophers of science:

(1) The more similarities between two domains, the stronger the analogy.

(2) The more differences, the weaker the analogy.

(3) The greater the extent of our ignorance about the two domains, the weaker the analogy.

(4) The weaker the conclusion, the more plausible the analogy.

(5) Analogies involving causal relations are more plausible than those not involving causal relations.

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(6) Structural analogies are stronger than those based on superficial similarities.

(7) The relevance of the similarities and differences to the conclusion must be taken into account.

(8) Multiple analogies supporting the same conclusion make the argument stronger.

Among these criteria, (1), (2), and (3) assess the analogy by examining similarities, differences, and unknowns between the two domains. Criteria (5), (6), and (7) involve deeper comparative factors such as causality, structural consistency, and relevance in similarity assessment. Criteria (4) and (8) represent general principles applicable to non-deductive arguments as a whole. In summary, the characterization in (1), (2), (3), (5), (6), and (7) is fundamentally based on the two keywords in the definition of analogy: **comparison** and **similarity**.

From a logical standpoint, however, these eight guidelines remain overly general and vague. Significant further work is required to translate them into truly actionable evaluation standards.

2. Lei Bi (类比) from the Chinese Tradition Encompasses Classification and Comparison

In Chinese, the term commonly used to translate "analogy" is "类比" (leibi). As previously discussed, the Western tradition largely defines analogy as a form of comparison emphasizing similarity. However, within the Chinese intellectual tradition, is "类比" understood merely as comparison?

Literally, "类比" consists of two characters: "类" (lei) and "比" (bi). While "比" denotes comparison, "类" carries meanings such as category, class, type, and classification. In fact, "类" is a conceptually significant term within Chinese traditional thought, suggesting that it serves a substantive, rather than merely decorative, role in the construct of "类比". Scholars specializing in the history of Chinese logic have observed distinctions between Chinese and Western conceptions of analogy. As Liu Peiyu emphasizes in an interview (Zhang to appear), "Compared to traditional Western analogy, Chinese analogy incorporates an additional requirement: **comparison within the same category**."

3. The Current Textbook Formalization of Analogy Cannot Distinguish Between Analogy and Metaphor

In current mainstream logic textbooks—which predominantly present the Western tradition of analogy theory (Logic Editorial Team 2018)—analogy or analogical reasoning is typically summarized as follows:

"Analogy is a form of inductive reasoning that infers further similarities between two things or two classes of things, based on existing similarities in certain respects."

This definition appears intuitive and has long been widely accepted. However, it fails to adequately distinguish between analogy and metaphor.

Consider the metaphor "lawyers are foxes." This metaphor is readily understood because both lawyers and foxes share the trait of "cunning," which lies at the heart of its interpretability. Beyond this central similarity, one could list numerous other commonalities: both are mammals, both are flammable, both possess minds, both have teeth, both can conduct electricity, and so on. According to the standard textbook definition of analogy, such a comparison would qualify as an analogical inference. Yet intuitively, we recognize this as a metaphor, not a typical analogy.

Thus, the conventional analogical reasoning framework fails to clearly separate analogy from metaphor (see Figure 1). Admittedly, from the Western theoretical perspective, metaphor can indeed be viewed as a form of comparison based on relational similarity. However, in common conceptual understanding, structural differences do exist between analogy and metaphor. The current textbook theory remains insufficient to capture this distinction.

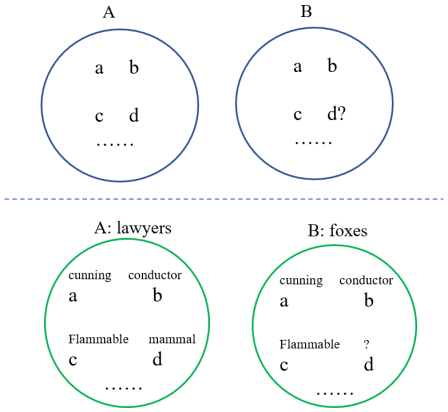

Figure 1: The textbook paradigm of analogy (above) cannot distinguish between analogy and metaphor(below).

It is worth noting that metaphor has garnered growing attention in the fields of linguistics and cognitive science over the past few decades. Through a wide range of examples, (Lakoff and Johnson 2003) illustrates the indispensable role of metaphor in human cognition. In (Juthe 2005), Juthe distinguishes between "same-domain analogy" and "different-domain analogy," arguing that when the two domains in a cross-domain analogy are sufficiently distant—and their constituent elements substantially different—the comparison is more likely to be perceived as a metaphor. In (Steinhart 2001), Steinhart introduces possible world semantics as a framework for analyzing metaphorical constructs.

However, these studies—particularly (Lakoff and Johnson 2003) and (Steinhart 2001)—remain situated within or constrained by certain specific categorical frameworks. This

paper seeks to move beyond such limitations and take a further step toward a generalized formalization of analogy.

Analogy Encompasses Classification and Comparison

This section analyzes the underlying reason for the divergence between Western and Chinese conceptions of analogy. It argues that this difference stems not from cognitive structure, but from the distinct evolutionary paths of their respective knowledge classification systems. Building on this analysis, the section contends that a robust theory of analogy should explicitly incorporate both classification and comparison. Furthermore, it demonstrates that introducing a categorical dimension offers a coherent and effective means of distinguishing between analogy and metaphor.

1. Key Differences in Emphasis Between Chinese and Western Conceptions of Analogy

Why did ancient Chinese thought place such strong emphasis on classification? A plausible explanation lies in the absence of a widely accepted classification system in ancient China. As Dong notes (Liu 2012), "Categories in ancient Chinese texts were far broader than scientific classifications. As long as two things or categories shared some similarity or resemblance in one aspect, they could be considered part of the same category."

By contrast, the Western scientific tradition developed a widely recognized system of classification. In ancient Greece, Aristotle introduced the genus-species model of classification, which still underlies modern taxonomic research. Although this system has been refined over time, its general framework has become the default within Western education and scientific discourse. Consequently, discussions within the Western tradition involve relatively fewer disputes over classification. It is not that classification is absent, but rather that a tacit, shared system of categories often operates within a given scope of discussion.

This leads to a reasonable conclusion: analogy fundamentally involves both classification and comparison. In ancient China, the lack of a unified classification consensus prompted extensive debates about categorical appropriateness. These discussions reveal more clearly the two core components of analogical thinking: classification and comparison. The Western conception of analogy, by contrast, can be viewed as a special case—one that emphasizes comparison against the background of an Aristotelian-style natural classification.

The root of this divergence lies not in cognitive mechanisms, but in knowledge structures. The debates among ancient Chinese scholars regarding the appropriateness of analogies illustrate that multiple methods and standards of classification can coexist. Scientific classification is but one influential form among many.

2. Classification Structure Effectively Distinguishes Between Analogy and Metaphor

According to (Hills 2024), "Metaphor is a poetically or rhetorically ambitious use of words, a figurative as opposed to literal use." Here, the defining feature of metaphor is summarized as being "opposed to literal use." But what does this mean in practice?

Consider the statement "lawyers are foxes." Under modern biological classification—the system typically reflected in dictionaries—lawyers are humans, while foxes are canines. Since the categories "human" and "canine" do not overlap, the claim "lawyers are foxes" does not correspond to factual reality. This mismatch exemplifies what is meant by "opposed to literal use." It is important to recognize, however, that this judgment relies specifically on contemporary biological taxonomy. From a logical standpoint, a proposition that contradicts facts may be considered false. Yet, whether a statement aligns with facts often depends on context, and determining the literal accuracy of "lawyers are foxes" is not strictly a matter of formal logic.

Inspired by the Chinese analogical principle of "comparison within the same category," we can reframe the notion of "opposed to literal use" in more general logical terms: metaphor identifies similarities across different categories. This formulation avoids reliance on content-specific judgments and removes the constraints of any particular classification system.

Moreover, this generalization clarifies both the connection and the distinction between analogy and metaphor: both can be viewed as forms of structured comparison. The key difference lies in the categorical relationship: analogy involves comparison within the same category, whereas metaphor involves comparison across different categories.

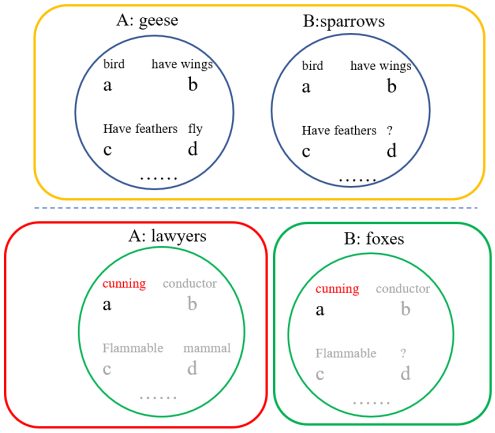

Figure 2: analogy involves comparisons within the same category (above), metaphor identifies similarities across different categories (below).

The distinction between same-category and cross-category comparisons provides an intuitive logical basis for differentiating analogy from metaphor. However, this categorical distinction alone does not fully capture the essence of metaphor.

Another intuitive difference lies in the perceived density of shared attributes: although both involve comparison, analogies are typically felt to involve more commonalities between the two objects than metaphors do. Yet this perception may be misleading. As previously discussed, lawyers and foxes actually share numerous similarities. Upon closer examination, it becomes apparent that the intuitive distinction reflects not a quantitative difference in commonalities, but rather that metaphor constitutes a more focused mode of comparison.

For instance, while lawyers and foxes share many traits—being mammals, flammable, having minds, legs, teeth, or being electrical conductors—the metaphor "lawyers are foxes" primarily highlights one salient characteristic: cunning. This trait represents a prototypical or paradigmatic similarity between the two. Thus, metaphor not only crosses categorical boundaries to identify commonalities across differences, but does so in a highly selective manner, concentrating on core properties meaningful to the comparison. Metaphor emphasizes qualitative relevance over quantitative overlap.

It should also be noted that although analogy and metaphor are conceptually distinct, the boundary between them is neither sharp nor fixed. According to the classification-and-comparison model, changes in classification criteria will alter what constitutes "same-category" versus "cross-category" comparison. This implies that the distinction between analogy and metaphor is inherently fluid and context-dependent.

Exploring the Formal Structure of Analogy

Building on the established understanding that analogy comprises both classification and comparison, this section proceeds to examine their formal structure—analyzing the organizational principles of classification and comparison individually, as well as their integrated compositional patterns.

1. The Structure of Comparison

As outlined in Section II, (Bartha 2024) compiles eight criteria for evaluating analogical arguments. While these criteria remain overly general and vague to serve as directly actionable evaluation standards, they nonetheless reveal several structural features inherent to comparison. These features will be reorganized and expanded upon here to form a basis for formalizing comparison.

To systematically discuss comparison and similarity, we must first consider what is being compared. Logic textbooks often illustrate analogy using property-based comparisons, yet relationships, proportions, structures, shapes, numbers, and other aspects may also serve as subjects of analogy. When comparing properties, it is necessary to determine whether a mere quantitative tally of similarities suffices, or whether a further distinction between essential and incidental attributes is required. Simple mathematical mappings may rely solely on quantitative matching, whereas comparisons involving everyday concepts typically entail more complex structural considerations. When comparing relationships, proportions, or other structured constructs, the configuration among the elements being compared must also be taken into account. Such elements may form ordered sets, which can then be compared as wholes.

Since logic is primarily concerned with formal rules, logical analysis often abstracts away specific content. Thus, properties, shapes, numbers, relationships, proportions, and structures can all be represented abstractly as comparative items denoted by symbolic labels. Where internal structure is relevant—such as when comparing relations or when the elements possess a significant ordering—this structure may be elaborated within a more refined formal framework.

Beyond the internal structure of individual items and ordered sets, external factors also play a role in comparison. Elements such as causality, correlation, and other background knowledge may extend beyond a straightforward comparison of two domains and warrant separate consideration. Furthermore, as the scope and depth of comparison expand, the criteria used to evaluate similarity are also likely to evolve in sophistication.

Since both simple and complex comparisons exist simultaneously, the following comparison methods are presented from simple to complex.

1) Compare the number of identical items.

2) Compare the quantity of identical items and the quantity of different items: both of which can form a ratio.

3) 2) pluses the ratio of known/unknown items: which requires a closeness assumption, see [9] for details.

4) Add structure to the comparative items: comparisons with structure are stronger than those based on individual properties.

5) To explain the essential attributes or core properties and the corresponding relationships: At this point, two types of comparative relationships may arise: one is the comparison between two objects or two systems of objects, the other is the comparison of indistinguishable relations or ordered relationships within a single object.

6) Introduce Causality: usually with arrow relation or probability.

7) Introduce topics: this aims to highlight relevance by focusing on analogous elements related to the discussion topic, essentially narrowing the scope of comparison to a subset of the original domain based on the initial scope.

8) Incorporate existing common sense or knowledge, or consider the influence of other ongoing comparisons: make decisions based on a certain ranking when comparison conclusions conflict, in order to avoid contradictions.

These schemes progress step by step, gradually increasing the complexity layer by layer. 1) to 3) are still considered quantitative comparisons. 4) and 5) correspond to discussions on structural analogy and intrinsic attributes. 4) corresponds to criterion (6) in (Bartha 2024) that structural analogy is stronger than analogy based on superficial similarity; 6) corresponds to criterion (5) in (Bartha 2024); 7) corresponds to criterion (7) in (Bartha 2024); 8) is a new scheme supplemented by this paper. 6) 7) and 8) may involve structures beyond those compared.

2. The Structure of Classification

Ancient Chinese literature contains extensive discussions on categorization. Among these, the Mohist school, particularly in the Mozi, systematically explores the principles of classification and the reasoning derived from it. The text outlines two foundational rules:

9) If things share similarities, they belong to the same category.

10) If things share no similarities, they do not form a category.

These principles, drawn from the Mozi (Sun 2019), establish a basic framework for classification. Beyond the Mohist tradition, texts such as the Lüshi Chunqiu and Huainanzi further analyze why categorical inferences cannot always be reliably drawn.

While 9) and 10) represent essential classification principles, relying solely on them would reduce analogy to mere comparison. This is because analogy inherently assumes that the two entities being compared share at least one similar attribute—otherwise, no basis for comparison would exist. If any two similar things can be compared, the requirement for a shared categorical framework in analogy appears to become superfluous.

However, the persistent historical debates over unreasonable analogies suggest that classification cannot be wholly reduced to 9) and 10). More nuanced categorical structures are clearly at work in practice. It is also important to note that such classification structures are indispensable for properly modeling comparison methods such as 7) and 8) introduced earlier.

2. The Structure of Classification

The introduction of classification into the formal structure enables the representation of diverse categorical systems. Several special cases of classification are worth noting:

Case 1: Universal Category. If everything is grouped into a single universal category, the distinction between analogy and metaphor collapses, as all comparisons become intra-categorical.

Case 2: Default Scientific Classification. This represents the conventional Western approach, where comparisons are conducted within a default, shared scientific classification system, forming the basis for traditional analogy.

Case 3: Fixed Schema Classification (e.g., 五行 Wu Xing). This is exemplified by the ancient Chinese Five-Elements (Wu Xing) schema—metal, wood, water, fire, and earth. This system imposed a rigid categorical framework where entities were often classified into these five categories, even if their intrinsic properties did not directly align with the elemental types.

Case 4: Parametric Classification based on Finite Property Sets. Here, categories are formed by partitioning objects using a predefined set of properties. For instance, things can be classified into three categories based on the property set {red, blue, other colors}.

3. The combinations of classification and comparison

The introduction of classification in the underlying structure, and the combination of classification and comparison will bring about a very huge impact.

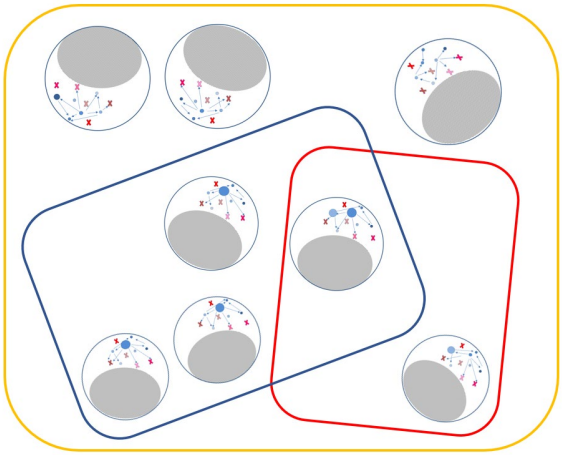

Figure 3: This diagram uses · to indicate identical or similar items, × to indicate different items, and the shaded area to represent unknown areas, the larger ● represents the essential attributes, →represent relationships or structures between elements. Different boxes represent different categories, with different topics, contexts, or classification criteria, etc.

a) Clarifying the Analogy–Metaphor Distinction and Its Fluidity. (Steinhart 2001) addresses metaphors that are "opposed to literal use" by introducing possible world semantics, thereby enabling their systematic analysis. While many of his technical contributions are valuable, his approach remains constrained by biological classification. Embedding classification as a structural component allows the distinction between analogy and metaphor to be expressed directly within the model, without relying on biologically-grounded judgments of literal truth. Furthermore, the interplay between classification and comparison naturally captures the fluidity between same-category and cross-category comparisons.

b) Enabling Richer Expressive Capacity through Flexible Combinations. Different configurations of classification and comparison provide expressive flexibility suited to diverse contexts. Classification effectively introduces a higher-order meta-perspective on comparison, facilitating the formal treatment of topics such as relevance, causality, and other contextual factors.

c) Establishing a Meta-Theoretical Framework for Cognitive Structures. Research on the structure of classification and comparison constitutes a form of meta-theoretical inquiry. Although Western analogy theory has not emphasized classification explicitly, scientific investigation is inherently classificatory—as seen in biological taxonomies, chemical periodic tables, and physical classifications. Crucially, however, studies of domain-specific classification systems differ fundamentally from research on the abstract structure of classification itself. In logic and artificial intelligence, the focus should be on cognitive structures—that is, a meta-theory of classification and comparison that underlies human and machine reasoning.

Possible Applications and Future Exploration

In the fields of artificial intelligence and automation research, classification methods have been widely applied in various forms. For instance, (Peng 2024) proposes a novel approach for optimizing heterogeneous structural entropy, which facilitates hierarchical clustering in social robotics—a technique that can be viewed as a practical implementation of classification. Similarly, (Tian 2024) investigates classification problems within the framework of machine learning. Advances in classification methodologies within computational network practices can, in turn, enrich theoretical research on the cognitive structures underlying classification and comparison.

This study, however, aims to highlight the importance of integrating classification as a foundational component within the underlying architectures of logical and artificial intelligence systems.

Currently, Large Language Models (LLMs) are increasingly influencing diverse aspects of human work and life. Yet, their internal mechanisms largely remain a "black box," introducing significant uncertainty and potential risks into both research and practical applications. There is, therefore, an urgent need to develop a fundamental theoretical understanding of LLMs. Given that current LLM development does not rely on classical logical frameworks, it is crucial to explore and reconstruct their logical foundations promptly, with the goal of transforming these models into "white-box" or at least "gray-box" systems.

In (Chen 2023), Chen examines the underlying mechanisms of LLMs through three axioms: contextual relevance, integrated monotonicity, and predictive choice. These axioms offer a partial explanation of how LLMs operate. At the same time, they reveal characteristics such as weak consensus and non-conceptualization in large models. On the other hand, effective large-scale communication generally requires a strong consensus background, and the scientific tradition has long relied on conceptualization to determine truth, falsehood, and validity. Whether a new pathway can be established for non-conceptual LLMs remains an open and critical question for future research.

Based on the aforementioned considerations, Chen advocates for reconstructing a logical foundation compatible with large models, addressing human-computer communication challenges within a strong-consensus framework, and building a bridge between conceptual and non-conceptual processing.

Classical logic's treatment of truth and falsehood is itself grounded in the concepts and classifications inherited from the scientific tradition. A central objective of this research, therefore, is to construct a more generalized logical framework capable of integrating the classical logic underlying human reasoning with the new logic emergent in large models.

Introducing classification as a core component of the cognitive architecture allows the current strong-consensus, conceptualized model—based on scientific classification—to be viewed as a special case derived from a specific categorical system. Conversely, the weak-consensus, non-conceptual processing of large models can be interpreted as a processing mode that either weakens classification or operates on dynamic, fluid categories. Consequently, by constructing a new logic that reinstates classificatory elements, both the logic of LLMs and the classical logic relied upon by humans can be incorporated as specific instances within a unified theoretical framework, thereby bridging the two paradigms.

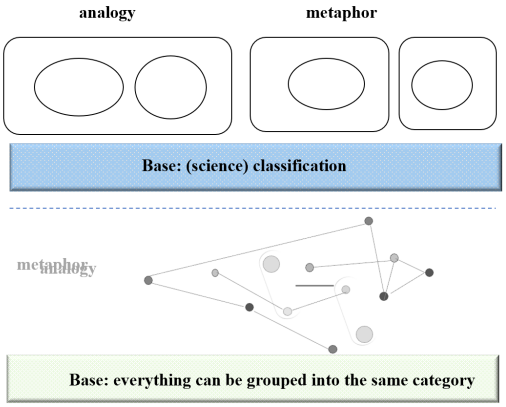

Figure 4: When classification is introduced, both cases above can be regarded as a special case of cognitive structures based on different classifications.

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Acknowledgments

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