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The Theoretical Foundations of Part–Whole Relations and Their Significance

Haydarov Anvar Askarovich
Professor at Bukhara State University
Email: a.a.haydarov@buxdu.uz

Shamsullayeva Dildora Sunnatullo qizi
Master's Degree Student, Bukhara State University
Email: shamsullayevadildora@gmail.com

Abstract. *This article examines the theoretical foundations of part–whole relations within the frameworks of formal mereology and linguistic meronymy. Particular attention is given to the logical properties of part–whole relations, including transitivity, asymmetry, and hierarchical organization. The study also analyzes structural and functional criteria that distinguish genuine parts from arbitrary fragments. By comparing formal logical approaches with cognitive and linguistic perspectives, the research demonstrates that human conceptualization plays a crucial role in interpreting part–whole relations. The findings suggest that although formal mereological models provide logical precision, they cannot fully capture the complexity of human cognitive processes. Therefore, an integrated approach combining formal and cognitive perspectives is essential for understanding part–whole structures in language, knowledge organization, and ontology design.*

Key words: *Part–Whole Relations, Mereology, Meronymy, Partonomy, Transitivity, Semantic Structure*

1. Introduction

Part–whole relations represent one of the most fundamental ontological models of human cognition. People rarely perceive reality as an undivided whole; rather, they interpret objects, events, and processes as structured systems composed of interconnected elements.[1] When individuals attempt to understand any phenomenon, they naturally identify its constituent parts and examine the relationships among them. For this reason, part–whole relations play an important role not only in philosophy and logic but also in cognitive science and linguistic semantics. [2]

The theoretical investigation of part–whole relations gained particular significance in the twentieth century. The philosophical works of Edmund Husserl and the logical system developed by Stanisław Leśniewski laid the foundations for modern mereology—the formal theory of parts and wholes. Later developments in semantics and cognitive science further expanded the understanding of these relations, particularly in studies of lexical semantics and conceptual classification.[3]

In linguistic research, part–whole relations are commonly discussed within the framework of meronymy, which describes semantic relations between a whole (holonym) and its components. However, empirical studies show that such relations cannot always be explained solely through formal logical principles.[4] Cognitive factors, perceptual structures, and functional interpretations often influence how speakers conceptualize and describe parts and wholes.The purpose of this study is to analyze the theoretical foundations of part–whole relations by integrating formal mereological principles with cognitive and linguistic perspectives.[5]

2. Methodology

The study employs a theoretical and analytical research methodology based on interdisciplinary literature from philosophy, formal ontology, and lexical semantics. The analysis focuses on several key theoretical sources, including studies of mereology, semantic relations, and cognitive models of conceptual structure. The research method includes:

Conceptual analysis of theoretical models of part–whole relations.

Comparative analysis of formal logical approaches and cognitive-semantic interpretations.[6]

Linguistic analysis of syntactic tests used to identify meronymic relations.

Particular attention is given to the criteria proposed in semantic and ontological studies for distinguishing genuine parts from arbitrary fragments. In addition, the taxonomy of part–whole relations developed by Winston, Chaffin, and Herrmann provides a framework for analyzing the logical behavior and cognitive interpretation of these relations.[7]

3. Results

The analysis shows that mereology traditionally describes part–whole relations through several logical principles, including transitivity, asymmetry, irreflexivity, and hierarchical organization. Within this formal framework, two basic processes define the relationship between parts and wholes:

Decomposition – the analysis of a whole into its constituent parts.[8]

Composition – the formation of a whole from its parts.

Although these principles provide logical clarity, they do not fully explain how humans actually perceive and conceptualize structural relations.[9]

From a phenomenological perspective, Edmund Husserl argued that a whole cannot be reduced to a simple sum of elements. Instead, a whole should be understood as a structured unity, where relationships among components create an integrated system.This perspective reflects the cognitive tendency to interpret objects as meaningful structures rather than as random collections of fragments.[10]

A particularly important distinction concerns the difference between parts and pieces. According to Gerstl and Pribbenow, not every fragment of an object can be considered a genuine part. A part must meet several criteria:

Structural integrity. A part is integrated into the internal structure of the whole. For example, the heart is a structural component of the human body, whereas a detached piece of tissue cannot necessarily be considered a body part.

Functional role. A part performs a specific function within the system. For instance, a wheel enables the movement of a car.[]

Non-arbitrariness. Parts are defined by natural structural boundaries rather than artificial divisions.

Human cognition relies on several criteria when identifying parts of an object, including perceptual boundaries, functional roles, structural integration, and prototypical representations.[12]

Another important issue concerns the transitivity of part–whole relations. In formal mereology, if A is part of B and B is part of C, then A should also be part of C. However, empirical research demonstrates that natural language and cognition do not always follow this strict logical pattern.

For example:

Handle → door

Door → house

Logically, this implies:

Handle → house

However, such expressions sound unnatural in everyday language because the concept of a

“house” represents a higher-level macrostructure. Speakers tend to avoid linking very small components directly to large structures.

Linguistic studies have also proposed syntactic tests for identifying partonomic relations. Two commonly used tests include:

“Y has Xs.”

“X is part of Y.”

For instance:

A hand has fingers.

A finger is part of a hand.

However, these tests do not capture all intuitive part–whole relations. Therefore, broader expressions such as “The parts of Y include X, Z, and others” are often used to describe partonomic structures.

Another factor concerns the distinction between necessary and optional parts. Some parts represent canonical components of a whole, while others are facultative elements. For example, a finger is a canonical part of a hand, whereas a handle is an optional component of a door.[13]

4. Discussion

The findings demonstrate that formal mereology provides an important theoretical foundation for analyzing part–whole relations, yet it cannot fully account for the complexity of human conceptualization. Cognitive models suggest that people interpret parts in relation to perceptual salience, functional relevance, and conceptual prototypes.[14]

Research in lexical semantics also highlights the role of part–whole relations in structuring conceptual knowledge and semantic hierarchies (Cruse, 2004). Similarly, semantic studies emphasize that human languages encode partonomic relations in ways that reflect cognitive universals and conceptual structures.

From this perspective, part–whole relations should be understood not merely as formal logical relations but also as cognitive-semantic structures shaped by human perception and experience.

This integrated perspective is particularly important in fields such as knowledge representation, ontology design, and information retrieval, where accurate modeling of conceptual relations plays a crucial role.[15].

5. Conclusion

Part–whole relations constitute a fundamental mechanism through which humans conceptualize and organize knowledge about the world. While formal mereology provides a logically rigorous framework for describing these relations, cognitive and linguistic evidence suggests that human conceptualization often diverges from purely formal models.

Understanding part–whole relations therefore requires an interdisciplinary approach that combines philosophical, linguistic, and cognitive perspectives. Such an approach not only improves theoretical models of semantic relations but also contributes to the development of more effective knowledge organization systems and conceptual ontologies.

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