A Trope-Theoretical Framework for Knowledge Representation

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Introduction

Big Data refers to datasets characterized by high volume, velocity, and variety, as well as complexity that challenges the capabilities of traditional data analytics tools. Its potential to generate insights and create economic, social, technical, and legal value makes semantic processing of Big Data crucial.

State-of-the-art statistical models, particularly large language models (LLMs), demonstrate impressive human-like linguistic capabilities but remain prone to hallucinations due to their nature. Thus, they are insufficient for a stand-alone semantic processing method. Conversely, manually structuring Big Data is impractical because of its sheer volume and complexity. Structured representations, such as ER models, taxonomies, or ontologies, struggle with interoperability despite decades of research, let alone their extreme cost. Furthermore, the dynamic nature of Big Data demands decentralized structures: manual structuring is also not a viable approach for semantic processing.

Recent technological advances focus on integrating ontologies with LLMs using methods like knowledge graph embeddings and ontology-based fine-tuning of LLMs. Since it remains uncertain, both theoretically and practically, whether combining these two methods can enable semantic processing of Big Data, research and experimentation in this area should continue. This paper, in contrast, proposes a foundational model for the dynamic semantic processing of Big Data with built-in explainability for the results.

Philosophical and Linguistic Background

In his *Tractatus Logico-Philosophicus*, Wittgenstein [1] represents a contingent world in the sense that it is mutable, conditioned, and not necessary [2]. This dynamic worldview hinges on the idea that the world consists of everything that is the case, which implies that *facts*, rather than *objects*, constitute its basic structures. As the world is resolved in facts, an object can appear in multiple facts, and it is within each fact that the object acquires its meaning. Accordingly, the ontological and epistemological status of an object is *relational*. Consequently, the traditional categorical perspective, representing the world in terms of objects and their interrelations, is replaced by a perspective that represents the world in terms of relations themselves.

In linguistics, *semantic properties* are the components of the meanings of words and sentences; for example, "human" is a semantic property of "student". They also define the semantic field of a word or a set of words [3]. For example, in "The assassin killed Thwacklehurst.", the semantic analysis identifies *assassin* as a *person* who *murders* someone *important*, typically for money or ideology. A *human* held the killing action, and *Thwacklehurst* was no ordinary citizen. Thus, the semantic field of "Thwacklehurst" includes "important person," "dead," and "murdered."

If properties are taken to furnish reality, then either they themselves or the entities emerging from their compositions can be seen as semantic properties. Interactions between entities (objects or relations) depend on specific semantic properties. Semantic analysis of a fact can identify which properties of the components are active in an interaction. For example:

> **fire|wood**: *fire* has the property of burning among its other properties, and *wood* had the property of being burned, among its other properties. When these two en-

tities interact, the mentioned properties will be in action, and *ash* will emerge.

water|hairdryer: *water* has the property of being an electrical conductor, and *hairdryer* has the property of being powered by electricity. In the context of having a shower, using a hairdryer in the shower can be fatal.

These examples illustrate that semantic processing involves identifying and interpreting the relevant semantic properties of entities in a given context. When the semantic properties of an entity are known, the allowable relations between entities can be deduced from their interactions.

Objective

This study proposes an alternative framework for knowledge representation, moving beyond statistical methods and the traditional object-relation dichotomy. Specifically, it suggests that a trope-theoretical framework can represent the world in terms of properties, which paves the way for the machine to deduce all possible relations between entities in contexts and produce dynamic and explainable results.

The trope theories, although philosophically disputed, state that tropes are the only ontological category that furnishes the world [4–6]. Tropes are the single entity type, whereas other types of entities are accounted for in terms of them. Paul [7, p. 33] states that "everything there is, including concrete objects like persons or stars, is a quality [property], a qualitative fusion, or a portion of the extended qualitative fusion that is the world-whole." Hence, the world can be constructed entirely from properties, viz., tropes.

Tropes are composed in a determined way to form entities. Analogous to a tangram, each tan represents a trope; different arrangements of tans represent different entities. For example, one combination may depict a goose, another a cat (Figure 1).

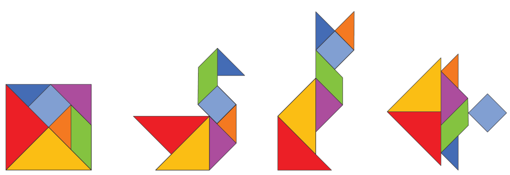

Figure 1: A set of tangs and some tangram figures

Methodology

A trope-theoretical approach aligns with both ontological and linguistic frameworks: Tropes are the fundamental constituents of reality and serve as semantic properties. A trope is a property, and a relation is an n-tuple property for any $n \geq 2$ ([8], cf. [9,10]). An entity is, then, either a trope or a trope composition.

When represented as a trope composition, each entity is assigned a unique trope-code that serves as its identifier. Each composition is unique, as in Figure 1, tangs may be the same, but their arrangement makes each composition distinct. Combinations of entities form secondary structures, which are likewise assigned their own trope-codes, and these can further combine into higher-order structures. Each of these higher-order codes encodes information about the possible combinations of entities within a structure, which is a context. An entity can not only be understood through its interactions with other trope compositions, and its all possible states can be determinable.

Discussion

Using tropes as the fundamental elements of being and representing the world through tropes and their compositions is philosophically grounded. A trope-theoretical approach thus yields a model of knowledge representation in which entities are defined by webs of properties, and interactions between these properties give rise to relations between entities. Explanations emerge from analyzing the allowable/possible relations among the semantic properties of interacting entities.

This model can be used as an ontology to represent reality in the machine. However, the nature of tropes and their connection to universals, the way relations interact, and the mechanisms for identifying and inferring outcomes from these interactions remain unclear. From a computational perspective, methods for processing these semantic properties and implementing this ontology are still open questions, as a trope-theoretical representation requires a mathematical foundation beyond set theories. Moreover, addressing the inherent complexity of such a structure is a necessary prerequisite for any implementation.

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