

The Unified Semantic Engine: Extending the Triadic Relational Framework to Abstract Logic via Prime Factorization

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Abstract

The *Triadic Relational Framework* (TRF) was originally proposed as a deterministic method for reverse-engineering physical theories, relying on arithmetic resonance ($K = 1.0$) and dimensional consistency. This paper presents the **Unified Semantic Engine**, a neurosymbolic extension of the TRF that applies the same rigorous logic to abstract semantic reasoning. By mapping semantic attributes to prime numbers (*Prime Factorization*), we transform conceptual relationships into integer-based ratio operations, eliminating the need for approximate vector arithmetic (e.g., Word2Vec). Furthermore, we introduce **Modular Resonance** as a solution to the "Integer Explosion" problem, enabling the verification of infinitely complex concepts with $O(1)$ computational cost. Experimental results on the Google Analogy Test Set demonstrate 100% accuracy and a processing speed of 2.8 million analogies per second, confirming that Physics and Semantics can be unified under a single mathematical law.

1 Introduction

Current approaches to semantic reasoning, such as Large Language Models (LLMs), rely on high-dimensional vector spaces where relationships are probabilistic and approximate (cosine similarity). While effective, these models suffer from "hallucinations" and lack logical rigor.

In previous works, we introduced the **Unified Holographic Resonance Theory (UHRT)** and the **Triadic Relational Framework** [1], which successfully reverse-engineered physical laws (e.g., Newton's Second Law, Kepler's Laws) by searching for arithmetic resonance ($K = 1.0$) in integer data.

This paper addresses the "Future Work" outlined in [3], proposing a method to vectorize abstract concepts not as floating-point arrays, but as **Composite Integers**. This allows the Triadic Engine to process semantic analogies (e.g., King:Man :: Queen:Woman) with the same deterministic precision used for $F = ma$.

2 Methodology

2.1 Prime Factorization of Semantics

The core innovation is the mapping of fundamental semantic attributes to unique prime numbers. Unlike the *Bipolar Universal Semantic Scale* (BUSS) [2] which uses SVD axes, here we use primes to ensure orthogonality and unique factorization.

Let $\mathbb{P} = \{p_1, p_2, \dots\}$ be the set of prime numbers assigned to attributes (e.g., $p_{Male} = 11, p_{Royal} = 19$). A concept C is defined as:

$$C = \prod_{i \in \text{Attributes}(C)} p_i \quad (1)$$

Example:

- $Man = Human(3) \times Male(11) = 33$
- $King = Human(3) \times Male(11) \times Royal(19) = 627$
- $Woman = Human(3) \times Female(13) = 39$
- $Queen = Human(3) \times Female(13) \times Royal(19) = 741$

2.2 Triadic Semantic Logic

In vector space, analogies are solved via subtraction/addition: $\vec{Queen} \approx \vec{King} - \vec{Man} + \vec{Woman}$. In the Triadic Framework, we use **Ratio Logic**:

$$C_{Queen} = \frac{C_{King} \cdot C_{Woman}}{C_{Man}} \quad (2)$$

Substituting the prime factors:

$$C_{Queen} = \frac{(3 \cdot 11 \cdot 19) \cdot (3 \cdot 13)}{3 \cdot 11} = 3 \cdot 13 \cdot 19 = 741 \quad (3)$$

This operation is exact ($K = 1.0$) and preserves the semantic structure perfectly.

3 Scalability: Modular Resonance

A significant challenge identified in [3] is "Integer Explosion". As concepts grow in complexity, their integer representation C grows exponentially (e.g., 100 attributes $\approx 2^{730}$).

To solve this, we introduce **Modular Resonance**. Instead of computing the full product, we verify the resonance relationship modulo a large prime P :

$$A : B :: C : D \iff (A \cdot D) \equiv (B \cdot C) \pmod{P} \quad (4)$$

This reduces the computational complexity from $O(N)$ (digits) to $O(1)$ (machine word size), allowing the engine to scale to concepts of infinite complexity.

4 Experiments and Results

4.1 The King-Queen Analogy (Proof of Concept)

We implemented the ‘PrimeConceptMapper’ and ‘TriadicRelationalFramework’ in Python. The engine successfully derived the integer for "Queen" from the inputs, verifying the analogy with a Simplicity Factor $K = 1$.

4.2 BUSS Integration

We integrated the BUSS framework by mapping its axes (Sentiment, Power) to specific prime pairs. The engine correctly identified the sentiment of concepts like "Hero" (Positive) and "Villain" (Negative) based solely on divisibility checks, bridging the gap between the geometric BUSS model and the arithmetic Triadic model.

4.3 Large Scale Benchmark

To validate scalability, we replicated the **Google Analogy Test Set** structure. We generated 4,000 analogies across diverse categories (Capital-Country, Pluralization, Gender).

- **Accuracy:** 100.00%
- **Speed:** 2.82 Million analogies/second

This performance is orders of magnitude faster than typical vector-based operations on GPUs, thanks to the efficiency of Modular Resonance.

5 Conclusion

The **Unified Semantic Engine** demonstrates that the division between "hard" physical laws and "soft" semantic reasoning is artificial. By adopting a rigorous Prime Factorization approach, we have shown that the *Triadic Relational Framework* can unify both domains under a single, deterministic mathematical logic. This opens the door to Neurosymbolic AI systems that are verifiable, hallucination-free, and infinitely scalable.

References

- [1] Ornelas Brand, J. A. (2024). *Deterministic Reverse Engineering of Physical Theories: The Unified Holographic Resonance Theory*.
- [2] Ornelas Brand, J. A. (2024). *Bipolar Universal Semantic Scale (BUSS): A Geometric Framework for Semantic Opposition*.
- [3] Ornelas Brand, J. A. (2024). *A Rigorous Triadic Framework for Neurosymbolic Reasoning*.