# Advanced Temporal Reasoning Features: Theoretical and Technical Review

Marco Confessore

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## Introduction

This document provides a comprehensive review of twelve advanced temporal reasoning features implemented in a TimeML-based temporal feature extractor. Each feature is analyzed with respect to its theoretical grounding, computational logic, and practical significance.

## Feature-by-Feature Review

### 1. Temporal Density

**Theory:** Measures temporal salience by normalizing the number of temporal markers (events and timexes) over text length.
**Formula:** Density = $\frac{\#Events+\#Timexes}{\text{Word Count}}$
**Rationale:** More temporally grounded narratives signal better grounding for reasoning or QA.
**Limitations:** Sensitive to short or sparse texts.

### 2. Temporal Complexity Score

**Theory:** Inspired by narrative structure and TimeML richness, this metric aggregates event/timex/TLINK count and type diversity.
**Formula:** Weighted sum of structural elements, normalized by length.
**Significance:** Reflects structural, semantic, and temporal narrative richness.

### 3. Temporal Coherence

**Theory:** Based on event graph theory and temporal logic.
**Method:** Constructs a temporal graph via TLINKs and evaluates connectivity and contradiction via path overlap.
**Value:** Highlights consistency of event-event or event-timex ordering.

### 4. Temporal Granularity Diversity

**Theory:** Drawn from the idea of multi-scale cognitive temporal reference.
**Approach:** Entropy-based score over detected granularities (e.g., minute, hour, decade).
**Advanced:** Uses regex, keywords, and contextual cues.
**Output:** Normalized entropy + diversity bonus.

### 5. Temporal Perspective Consistency

**Theory:** Based on tense stability in narratology.
**Extraction:** Measures dominant tense and penalizes switches (e.g., past to future).
**Implication:** High score = stable temporal point of view.

### 6. Temporal Anchoring Strength

**Theory:** Based on Reichenbach's reference time anchoring.
**Method:** Checks if events are linked to specific times via TLINKs.
**Enhancement:** Bonus for ISO-like or normalized timex values.

### 7. Temporal Narrative Flow

**Theory:** Rhetorical Structure Theory and discourse connectives.
**Technique:** Counts presence and diversity of temporal discourse markers (e.g., then, while, because).
**Goal:** Fluency and chronological control in storytelling.

### 8. Temporal Disambiguation Quality

**Theory:** Distinguishes vague from specific temporal language.
**Method:** Identifies ambiguous expressions (e.g., "soon") and rewards normalized timexes.
**Metric:** Specific count + normalization bonus.

### 9. Temporal Reference Precision

**Theory:** Precision grading for temporal references based on format.
**Scale:** ISO datetime = 1.0, vague words = 0.2.
**Use Case:** Highlights reliability for retrieval or QA tasks.

### 10. Temporal Logical Consistency

**Theory:** Allen's interval algebra and contradiction detection.
**Technique:** Checks if inferred paths via TLINKs contradict direct relations.
**Application:** Useful in verifying logical soundness of timelines.

### 11. Temporal Semantic Richness

**Theory:** Lexical-semantic variation in event and time types.
**Mechanism:** Uses diversity of event classes, aspects, and timex complexity.
**Implication:** Measures depth of temporal representation.

### 12. Temporal Syntactic Integration

**Theory:** Syntax-pragmatic embedding of time expressions.
**Heuristic:** Checks for prepositions/auxiliaries in local context of temporal elements.
**Benefit:** Reflects grammatical fluency of temporal anchoring.

## Conclusion

This feature set provides a rich toolkit for analyzing temporal reasoning in text, particularly useful for distinguishing human vs. AI temporal narratives, validating timeline quality, or powering downstream NLP models.