**Temporal-Uncertainty Biomedical Knowledge Graphs: Tracking the Evolution of Scientific Confidence**

**Introduction**

The biomedical research landscape is experiencing unprecedented growth, with over 1 million new papers published annually in PubMed alone. This massive influx of information creates significant challenges for researchers attempting to synthesize current knowledge. While recent advances in Natural Language Processing (NLP) and Knowledge Graph technologies have enabled automated extraction of biomedical relationships from literature, current systems fail to capture two critical dimensions: how scientific understanding evolves over time and the varying levels of certainty associated with extracted knowledge.

**The Problem**

Current biomedical knowledge systems suffer from several limitations:

1. **Static representation**: Most knowledge graphs represent biomedical relationships as binary (exists/doesn't exist) rather than evolving entities that change as new evidence emerges.
2. **Certainty blindness**: Extracted relationships are typically treated with equal confidence, failing to distinguish between well-established facts and emerging hypotheses.
3. **Missing contradictions**: Systems rarely capture competing explanations or contradictory findings, leading to an incomplete picture of scientific discourse.
4. **Temporal flattening**: The evolution of scientific understanding—including superseded theories, emerging consensus, and shifting paradigms—is lost in most knowledge representations.

As a result, researchers must manually track the historical development and confidence level of biomedical relationships, a process that becomes increasingly infeasible as literature volume grows.

**Our Solution**

We propose developing a Temporal-Uncertainty Biomedical Knowledge Graph framework that explicitly models both the evolution of scientific understanding and the confidence associated with biomedical relationships. Our system will:

1. **Track temporal dynamics**: Extract and represent when specific relationships were first proposed, gained acceptance, were challenged, or modified based on publication timestamps and citation patterns.
2. **Model uncertainty levels**: Classify relationships on a spectrum from established facts to speculative hypotheses based on evidence patterns and consensus indicators.
3. **Visualize knowledge evolution**: Provide interactive visualizations showing how specific relationships have evolved over time, including competing explanations and periods of scientific controversy.

**Technical Approach**

Our implementation will combine:

* Transformer-based NLP models fine-tuned for biomedical literature to extract relationships and their temporal context
* Temporal knowledge graph architectures with time-aware embeddings to represent varying certainty states
* Citation network analysis for tracking influence, consensus formation, and knowledge evolution

**Expected Impact**

This system will enable researchers to:

* Quickly assess the current consensus on specific biomedical relationships
* Identify emerging trends and actively evolving knowledge areas
* Understand historical context and development of scientific ideas
* Recognize knowledge gaps and contradictions requiring further investigation

By representing both temporal dynamics and uncertainty in biomedical knowledge, our system will provide a more nuanced and accurate picture of scientific understanding, ultimately accelerating discovery and reducing time spent on literature synthesis.

**The Problem**

* A traditional knowledge graph with uniform nodes and connections
* All relationships appear identical (same line thickness and style)
* No indication of when relationships were established or how confident we should be in them
* Key problems listed:

1. Static representation (no temporal evolution)
2. Binary relationships (no uncertainty levels)
3. Missing contradictions and competing theories
4. No historical context of knowledge evolution

**Our Solution**

* + A timeline-based knowledge graph (2010-present)
  + Nodes that grow in size as evidence accumulates
  + Different colored nodes representing:

1. Orange nodes: Initial hypotheses
2. Green nodes: Established knowledge
3. Red nodes: Competing theories
4. Blue nodes: Emerging research
   * Varying connection styles:
5. Dotted/thin lines for uncertain relationships
6. Solid/thick lines for well-established relationships
   * Shows how competing theories can branch from the same evidence
   * Demonstrates how consensus forms over time as certain theories gain support