

Position-Candidate-Hypothesis (PCH) Paradigm: A Structural-Statistical Approach to NP-Complete Problems

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November 15, 2025

Abstract

Abstract: This research paper introduces the Position-Candidate-Hypothesis (PCH) paradigm as a novel theoretical approach to NP-complete problems. This work proposes a fundamental shift from traditional combinatorial search to structural-statistical analysis. The research explores the decomposition of problems into three interconnected components: positions, candidates, and hypotheses, followed by statistical integration. This work presents a new perspective on computational problem-solving that emphasizes structural analysis and pattern recognition over exhaustive search methods.

Keywords: NP-complete problems, PCH paradigm, theoretical computer science, structural analysis, computational complexity

Introduction

NP-complete problems represent one of the most profound challenges in computational complexity theory. Traditional methodologies, predominantly based on combinatorial search and heuristic optimization, have provided valuable insights but face inherent limitations in scalability and generalizability.

This paper introduces the Position-Candidate-Hypothesis (PCH) paradigm—a theoretical approach that reconceptualizes NP-complete problems through the lens of structural-statistical analysis. Rather than focusing on improved search algorithms, PCH proposes a fundamental rethinking of how we represent and approach computational complexity.

Research Context. The PCH paradigm continues a line of inquiry established in our previous work on paradigm shifts in computing. It shares the philosophical foundation of the Pointer-Based Security Paradigm [4], which argued for replacing data protection with architectural elimination of vulnerable data, and the Local Data Regeneration Paradigm [5], which proposed shifting from data transmission to synchronous state discovery. The present work applies a similar structural-philosophical approach to the domain of computational complexity and NP-complete problems.

The PCH Paradigm

The PCH paradigm is founded on a structural decomposition approach:

- **Positions** represent the fixed structural elements of a solution
- **Candidates** constitute the assignable entities to these positions
- **Hypotheses** represent independent investigative processes
- **Statistical Integration** synthesizes findings across hypotheses

This approach shifts the focus from permutation spaces to structured component analysis.

Core Components

Positions: The Structural Foundation

Positions define the architectural structure of a solution. In any NP-complete problem of size n , positions represent the n structural slots that must be filled to constitute a complete solution. Each position carries specific constraints, relationships, and requirements that influence candidate suitability.

Candidates: The Assignment Space

Candidates represent the entities available for assignment to positions. The approach considers n candidates for analysis, with each candidate evaluated against position-specific criteria. Candidate assessment incorporates multidimensional metrics including compatibility, optimization potential, and constraint satisfaction.

Hypotheses: Independent Investigation Processes

Hypotheses embody the core investigative mechanism of the PCH paradigm. For a problem of size n , exactly n hypotheses are employed, each initiating from a unique starting configuration:

- Hypothesis h_1 begins with candidate c_1
- Hypothesis h_2 begins with candidate c_2
- ...
- Hypothesis h_n begins with candidate c_n

Each hypothesis conducts comprehensive research across all positions, exploring candidate assignments and solution pathways independently.

Methodological Approach

Parallel Investigation

The PCH approach enables simultaneous multi-hypothesis investigation:

- All n hypotheses execute concurrently
- Each hypothesis maintains independent research trajectory
- Cross-hypothesis contamination is minimized
- Diverse solution pathways are explored simultaneously

This natural parallelism makes the approach particularly suitable for emerging computational architectures, including quantum and massively parallel systems.

Structural Analysis

Unlike traditional approaches that traverse permutation spaces, PCH focuses on:

- Position-candidate compatibility analysis
- Structural constraint propagation
- Relationship mapping between positions
- Pattern emergence across hypotheses

Statistical Synthesis

After hypothesis completion, statistical methods integrate findings:

- Consensus pattern identification
- Solution confidence estimation
- Anomaly detection and analysis
- Optimal solution derivation

Theoretical Foundations

Philosophical Shift

PCH represents a paradigmatic shift in computational thinking:

- **From search to structure** - Emphasizing architectural analysis over combinatorial traversal
- **From sequential to parallel** - Leveraging simultaneous investigation pathways
- **From deterministic to statistical** - Employing probabilistic synthesis over exact computation
- **From black-box to interpretable** - Providing transparent solution derivation

Cognitive Alignment

The PCH approach aligns with human problem-solving approaches:

- Multiple hypothesis testing in scientific discovery
- Parallel consideration of alternatives
- Structural understanding before detailed analysis
- Pattern recognition over exhaustive enumeration

Application Spectrum

The PCH paradigm offers a unified approach to diverse NP-complete problems:

Traveling Salesman Problem

- Positions: Cities in the travel sequence
- Candidates: Cities available for each position
- Hypotheses: Different starting city investigations

Boolean Satisfiability

- Positions: Variable assignments in the formula
- Candidates: Truth value assignments
- Hypotheses: Different initial assignment strategies

Graph Coloring

- Positions: Vertices to be colored
- Candidates: Available colors
- Hypotheses: Various initial coloring approaches

Research Implications

Theoretical Contributions

- Novel problem decomposition methodology
- Unified approach for NP-complete analysis
- Structural-statistical synthesis perspective
- Parallel investigation paradigm

Practical Potential

- Natural parallelization capabilities
- Interpretable solution processes
- Scalable investigation approach
- Cross-problem methodology transfer

Conclusion and Future Directions

The Position-Candidate-Hypothesis paradigm represents a significant theoretical contribution to computational complexity theory. By shifting focus from combinatorial search to structural-statistical analysis, PCH opens new avenues for understanding and approaching NP-complete problems.

Future research directions include:

- Formal mathematical foundation development
- Empirical validation across problem domains
- Hybrid approaches combining PCH with existing methods
- Implementation strategies for parallel architectures
- Quantum computing applications

The PCH paradigm demonstrates that fundamental advances in computational problem-solving may emerge not from faster search methods, but from reconceptualizing the very nature of the problems we seek to solve.

Research Perspective

This paper presents a theoretical perspective for conceptualizing NP-complete problems. The PCH paradigm represents a philosophical and methodological approach rather than a specific algorithm implementation. The value of this work lies in its potential to stimulate new ways of thinking about computational complexity and problem-solving strategies.

References

- [1] Cook, S. (1971). The complexity of theorem-proving procedures
- [2] Karp, R. M. (1972). Reducibility among combinatorial problems
- [3] Garey, M. R., Johnson, D. S. (1979). Computers and Intractability: A Guide to the Theory of NP-Completeness
- [4] Suvorov, A. (2025). The Pointer-Based Security Paradigm: Architectural Shift from Data Protection to Data Non-Existence. Zenodo. <https://doi.org/10.5281/zenodo.17204738>
- [5] Suvorov, A. (2025). The Local Data Regeneration Paradigm: Ontological Shift from Data Transmission to Synchronous State Discovery. Zenodo. <https://doi.org/10.5281/zenodo.17264327>