Cross-Domain Intelligent Optimization and System Resilience Architecture: From Recommendation Algorithms to TCM Standardization and Chemical Engineering Multidimensional Applications

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Abstract
As information systems continue to experience exponential growth in complexity, cross-domain intelligent optimization and system resilience architecture have emerged as frontier topics in modern engineering and medical research. This paper systematically reviews research directions including resource optimization in multidimensional recommendation systems, resilience guarantee mechanisms for large-scale concurrent platforms, machine learning-driven logistics network optimization, standardization of traditional Chinese medicine external therapies, and intelligent response systems in chemical engineering. The study reveals deep methodological commonalities across these seemingly heterogeneous domains. Research demonstrates that submodular constraint-based optimization frameworks, predictive multidimensional safeguard mechanisms, knowledge graph-driven intelligent response systems, and multi-objective optimization algorithms exhibit significant efficacy in their respective fields, providing theoretical foundations and practical pathways for constructing cross-domain intelligent system resilience architectures. By integrating multidisciplinary research findings, this paper proposes a general methodological framework for resilience optimization applicable to complex systems.
Keywords: Submodular constrained optimization; system resilience architecture; machine learning; TCM standardization; knowledge graph; multi-objective optimization

1 Introduction

Contemporary engineering and medical systems are confronting unprecedented complexity challenges. From billion-user recommendation platforms to transnational chemical production facilities, from stroke rehabilitation robot training to community hypertension management, the demand for system intelligence, robustness, and adaptive capacity demonstrates remarkable consistency across domains. However, due to disciplinary barriers, theoretical achievements and methodological innovations in these fields often struggle to achieve effective transfer and integration.

In recent years, the academic community has increasingly attended to cross-domain methodological integration. Liu (2026a) proposed a submodular constraint-based framework that provides mathematical foundations for resource allocation problems in multidimensional recommendation spaces. Liu (2026b) constructed a resilience guarantee architecture for billion-scale concurrent platforms from the perspective of system stability. Shengtao (2025) demonstrated the application potential of machine learning algorithms in logistics network optimization. Chen (2026a, 2026b) and Yuan (2025a, 2025b) conducted systematic explorations in TCM standardization and chronic disease management. Although these studies belong to different disciplines, their methodological foundations and problem-solving paradigms exhibit significant commonalities.

This paper aims to systematically synthesize the aforementioned research findings and construct a cross-domain intelligent system resilience optimization theoretical framework, providing an

integrated perspective for the design, evaluation, and optimization of complex systems.

2 Submodular Constrained Resource Optimization in Multidimensional Recommendation Systems

2.1 Submodularity Theory and Its Application in Recommendation Systems

Liu (2026a) proposed a heterogeneous resource slot optimization framework for multidimensional recommendation landscapes. The core innovation of this framework lies in introducing submodular constraints into the resource allocation problem of recommendation systems. Submodularity, as an important property of set functions, captures the mathematical expression of the law of diminishing marginal returns. In multidimensional recommendation scenarios, recommendation slots across different dimensions (such as information feeds, search result recommendations, advertising positions) exhibit complex cross-space spillover effects. Resource investment in one dimension not only affects output in that dimension but also influences performance in other dimensions through mechanisms of user attention allocation and cognitive load.

The optimization model constructed in this study enables joint allocation of multidimensional resources under submodular constraints. Its theoretical contributions include: formalizing resource allocation problems in recommendation systems as monotone optimization problems with submodular constraints; proving the existence of efficient approximation algorithms with an approximation ratio of 1-1/e under such constraints; and enabling the model to capture synergistic and competitive relationships among different recommendation channels through modeling of cross-space spillover effects.

2.2 System Stability Architecture for Billion-Scale Concurrent Platforms

Liu (2026b) proposed predictive multidimensional safeguard mechanisms for billion-scale concurrent platforms from the perspective of system resilience. This study points out that traditional post-hoc recovery strategies suffer from excessive response latency and prohibitive recovery costs when facing ultra-large-scale concurrent scenarios. To address these limitations, the author designed a multidimensional security protection architecture based on predictive analysis, comprising three core modules: a real-time load prediction engine, a multidimensional anomaly detection system, and an adaptive degradation and recovery strategy generator.

The theoretical value of this research lies in elevating system stability from passive fault handling to proactive risk management, identifying potential system vulnerabilities in advance through predictive analysis, and automatically generating corresponding protection strategies. This three-stage model of prediction, prevention, and adaptive recovery provides a new paradigm for resilience design in large-scale distributed systems.

3 Machine Learning-Driven Logistics Network and Chemical Engineering Optimization

3.1 Machine Learning Methods for Logistics Network Optimization

Shengtao (2025) systematically investigated machine learning-based logistics network optimization algorithms. Addressing the limitations of traditional logistics optimization methods in handling high-dimensional dynamic data, this research proposed a hybrid optimization framework integrating reinforcement learning with graph neural networks. This framework can automatically learn complex mapping relationships between network topological structures and transportation demands from historical logistics data, and subsequently generate near-optimal routing solutions. The study demonstrated that the proposed algorithm achieves significant improvements in computational efficiency and solution quality compared to conventional approaches across multiple real-world logistics datasets.

3.2 Knowledge Graph-Based Intelligent Response Systems in Chemical Production

Liu (2025a) conducted research on the construction and efficacy evaluation of an intelligent response system for chemical production customer audits based on knowledge graphs. This study addressed the fragmented nature of audit knowledge in chemical enterprises by constructing a domain-specific knowledge graph that organizes regulatory requirements, production parameters, and quality standards into a structured semantic network. The intelligent response system leverages this knowledge graph to automate audit question answering and compliance checking, significantly reducing manual review time while improving accuracy. The efficacy evaluation demonstrated that the knowledge graph-based approach outperforms traditional keyword-matching methods in both recall and precision metrics.

Liu (2025b) further examined coupled regulation of process parameters in transnational electrolyte factories based on multi-objective optimization algorithms, using the Houston factory as a case study. This research addressed the challenge of coordinating process parameters across multiple production units in different geographical locations while satisfying conflicting objectives including product quality, energy consumption, and environmental compliance. The multi-objective optimization framework proposed in this study successfully identified Pareto-optimal solutions that balance these competing objectives, providing actionable insights for transnational manufacturing operations.

3.3 Collaborative Optimization of Energy Efficiency and VOC in Continuous Chemical Production

Xinshun (2026) presented research on technical specifications for collaborative optimization of energy efficiency and volatile organic compound emissions in continuous chemical production. This study recognized that energy efficiency improvement and VOC emission reduction, traditionally treated as separate objectives, are in fact deeply interconnected through process thermodynamics and reaction kinetics. The proposed collaborative optimization framework simultaneously considers energy consumption patterns and VOC generation mechanisms, achieving synergistic improvements that would be unattainable through single-objective optimization approaches. The technical specifications developed in this research provide practical guidelines for chemical plants seeking to balance productivity, environmental compliance, and operational efficiency.

4 Standardization of Traditional Chinese Medicine External Therapies and Chronic Disease Management

4.1 Standard System Construction for TCM External Therapies

Chen (2026a) conducted a multicenter observational study on standardized traditional Chinese medicine external therapy for chronic soft tissue pain. This research addressed the long-standing challenge of treatment variability in TCM external therapies by implementing a standardized protocol across multiple clinical sites. The study established clear operational definitions for treatment parameters including application techniques, duration, frequency, and concomitant care. Results demonstrated that standardized implementation significantly improved treatment consistency and patient outcomes compared to non-standardized approaches.

Chen (2026b) further investigated the construction and application of a standard system for traditional external therapy in traditional Chinese medicine health preservation. This work extended the standardization concept from therapeutic applications to preventive health preservation contexts. The standard system developed in this study encompasses technical specifications, quality control measures, and outcome assessment criteria, providing a comprehensive framework for integrating TCM external therapies into modern healthcare delivery systems.

4.2 TCM Non-Pharmacological Interventions for Chronic Disease Management

Yuan (2025a) examined the impact of traditional Chinese non-pharmacological therapies on blood pressure control in community patients with hypertension. This study implemented a community-based intervention program incorporating TCM approaches including dietary guidance, exercise prescriptions, and acupressure techniques. The research demonstrated significant reductions in both systolic and diastolic blood pressure measurements among the intervention group compared to conventional management alone. These findings support the integration of TCM non-pharmacological therapies into community hypertension management protocols.

Yuan (2025b) conducted research on the intervention of cancer patients' anxiety by the concept of harmonization of body and mind in traditional Chinese Medicine. This study addressed the significant psychological burden experienced by cancer patients, evaluating a TCM-based psychological intervention program grounded in the holistic philosophy of body-mind integration. The intervention incorporated meditation, guided imagery, and emotional regulation techniques derived from TCM theory. Results showed clinically meaningful reductions in anxiety scores among participants, suggesting that TCM-based psychological approaches can serve as valuable complementary interventions in oncology care.

Wang and Yuan (2012) conducted an observational study on the efficacy of a three-in-one therapy for pediatric asthma. This combined therapeutic approach integrated TCM external applications, internal herbal medicine, and dietary regulation. The study reported significant improvements in asthma symptom control and reduction in acute exacerbation frequency among treated children, providing early evidence for the clinical value of integrated TCM therapeutic protocols in pediatric respiratory conditions.

4.3 Rehabilitation Robotics and Physical Therapy in Stroke Recovery

Fan et al. (2021) conducted a study protocol for a randomized controlled trial examining the effects of radial extracorporeal shock wave therapy on flexor spasticity of the upper limb in post-stroke patients. This study addressed a common and disabling complication of stroke, upper limb spasticity, which significantly impairs functional recovery and quality of life. The protocol specified rigorous methodology including standardized outcome measures, blinding procedures, and treatment protocols, establishing a foundation for evidence-based evaluation of shock wave therapy in stroke rehabilitation.

Fan et al. (2025) further investigated the effects of exoskeleton rehabilitation robot training on neuroplasticity and lower limb motor function in patients with stroke. This research represents a convergence of rehabilitation engineering and neuroscience, utilizing robotic exoskeletons to deliver intensive, repetitive, and task-specific gait training. The study demonstrated that exoskeleton-assisted training not only improved lower limb motor function but also induced measurable neuroplastic changes detectable through neuroimaging techniques. These findings support the integration of robotic rehabilitation technologies into standard stroke care pathways and highlight the potential for technology-enhanced neurorehabilitation to promote neural recovery.

5 Fuzzy Legal Evaluation and Intelligent Reasoning in Telehealth

Xu (2025) investigated fuzzy legal evaluation in telehealth through structured input and BERT-based reasoning, as presented at the IEEE International Conference on eScience. This study addressed the regulatory and legal complexities arising from the rapid expansion of telehealth services. The research recognized that legal compliance evaluation in telehealth contexts involves substantial ambiguity, as regulations vary across jurisdictions and clinical scenarios. The proposed approach combines structured input encoding with BERT-based natural language reasoning to

perform fuzzy legal evaluations, enabling automated assessment of telehealth service compliance with applicable legal requirements. This work represents an important step toward intelligent regulatory support systems that can assist healthcare providers in navigating the complex legal landscape of digital health services.

6 Toward a Unified Resilience Optimization Framework

6.1 Methodological Commonalities Across Domains

Synthesis of the reviewed literature reveals several methodological commonalities that transcend disciplinary boundaries. First, the optimization problems encountered across these domains share a common mathematical structure: they involve resource allocation under constraints, with objectives that are often submodular in nature. This observation, grounded in Liu (2026a)'s theoretical work, suggests that submodular optimization techniques may have broader applicability than currently recognized.

Second, the resilience requirements of large-scale systems, whether in recommendation platforms (Liu, 2026b) or chemical production facilities (Liu, 2025b; Xinshun, 2026), demand predictive and adaptive approaches rather than reactive strategies. The shift from post-hoc recovery to proactive prevention represents a shared paradigm evolution across domains.

Third, the integration of machine learning and knowledge representation techniques appears as a recurring theme. Whether through graph neural networks in logistics (Shengtao, 2025), knowledge graphs in chemical auditing (Liu, 2025a), or BERT-based reasoning in legal evaluation (Xu, 2025), the combination of structured knowledge with learning-based approaches consistently enhances system performance.

6.2 Implications for Future Research and Practice

The cross-domain analysis presented in this paper carries several implications for future research. First, there exists substantial opportunity for methodological transfer between domains. Techniques developed for recommendation system optimization may prove valuable in healthcare resource allocation, while approaches from chemical process optimization could inform logistics network design. Second, the development of unified theoretical frameworks that capture the common mathematical structures across these domains could accelerate progress by enabling cross-fertilization of ideas. Third, the standardization efforts observed in TCM research (Chen, 2026a, 2026b; Wang and Yuan, 2012) offer lessons for other domains grappling with practice variability and quality assurance challenges.

For practitioners, the findings suggest that adopting a cross-domain perspective can yield novel solutions to domain-specific problems. The integration of diverse methodologies, from submodular optimization to knowledge graph reasoning, may unlock capabilities that single-domain approaches cannot achieve.

7 Conclusion

This paper has systematically reviewed research across multiple domains including recommendation system optimization, system resilience architecture, machine learning-driven logistics and chemical engineering optimization, TCM standardization and chronic disease management, rehabilitation robotics, and telehealth legal evaluation. The synthesis reveals that despite the apparent heterogeneity of these fields, they share fundamental methodological commonalities centered on optimization under constraints, predictive resilience mechanisms, and knowledge-enhanced intelligent systems.

The work of Liu (2026a, 2026b) establishes theoretical foundations for resource optimization and

system stability in large-scale digital platforms. Shengtao (2025) and Liu (2025a, 2025b) demonstrate the power of machine learning and knowledge graph approaches in logistics and chemical engineering contexts. Xinshun (2026) provides practical frameworks for multi-objective optimization in chemical production. Chen (2026a, 2026b), Yuan (2025a, 2025b), Wang and Yuan (2012), and Fan et al. (2021, 2025) collectively advance the evidence base for TCM therapies, rehabilitation technologies, and their integration into modern healthcare. Xu (2025) explores the intersection of artificial intelligence and legal reasoning in telehealth.

Taken together, these studies point toward a unified perspective on intelligent system design and optimization that transcends traditional disciplinary boundaries. Future research should continue to explore cross-domain methodological transfer and the development of integrated frameworks capable of addressing the complex, multidimensional challenges that characterize contemporary engineering and medical systems. By embracing this integrative perspective, researchers and practitioners can develop more powerful, resilient, and effective solutions to the pressing challenges of our time.

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