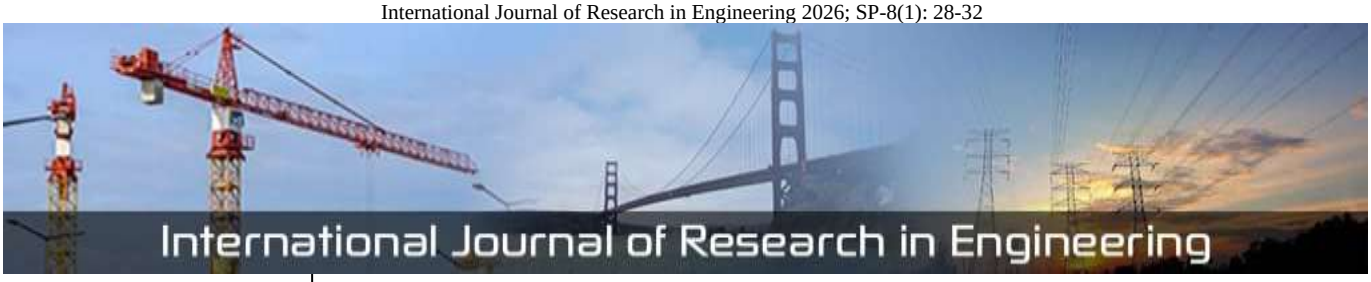

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Computational synthesis and preservation: The role of artificial intelligence in modelling the Indian knowledge system (IKS)

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Abstract
The confluence of Artificial Intelligence (AI) and the Indian Knowledge System (IKS), or the *Bhāratīya Jñāna Paramparā*, presents a critical area for computational modeling, digital preservation, and algorithmic innovation. This paper provides an academic analysis of current methodologies, including Natural Language Processing (NLP) for ancient textual preservation and specialized computational paradigms derived from IKS principles. Empirical evidence demonstrates tangible success in hardware optimization through Vedic Mathematics [1] and the formalization of spatial planning using Graph Machine Learning (GML).[2] However, results from benchmarking efforts in complex domains, such as traditional medicine (Ayurveda), indicate significant limitations in AI's ability to achieve genuine conceptual and integrative understanding.[3] The sustainable and ethical integration of IKS necessitates immediate action to standardize fragmented data [4], establish transparent ethical and intellectual property frameworks, and adopt hybrid AI architectures inspired by indigenous formal logic systems like Nyāya.[5]

Keywords: Indian Knowledge System (IKS), Graphical machine learning, Artificial intelligence, hybrid AI structure

1. Introduction

1.1. The Digital Preservation Imperative and IKS Domains

The Indian Knowledge System (IKS) represents a vast repository of traditional wisdom encompassing fields developed over millennia, including mathematics, astronomy, medicine, architecture, and advanced philosophical logic [6]. Recognizing the value of this heritage, the Ministry of Education of the Government of India established the IKS division in October 2020 to promote the inclusion of these systems into modern educational curricula and apply ancient knowledge to solve contemporary issues, such as climate change and healthcare.[6] This institutionalization aligns with the National Education Policy (NEP) 2020, which emphasizes integrating IKS at all educational levels [7].

The central challenge in promoting IKS today is not merely recognition but the systematic, digital preservation and computational modeling of this fragmented, multilingual heritage. Globalization and modernization risk the loss of traditional practices and documentation, necessitating robust governmental and technological intervention [6].

1.2. The Dual Function of AI in IKS Research

Artificial Intelligence serves two primary, interrelated functions within this research context: AI as an archival tool and IKS as a foundational model. First, AI technologies, particularly NLP and computer vision, are essential archival tools required to overcome the physical and linguistic barriers associated with ancient texts [9]. Many original IKS manuscripts are inaccessible, incomplete, or fragmented, having been written on non-standard media like palm leaves [4]. AI facilitates the necessary tasks of digitization, transcription, translation, and semantic structuring to bring these systems into a searchable and analyzable format. Second, IKS itself functions as a profound foundational model for AI. Disciplines like Nyāya (Logic) provide highly structured methodologies for sound inference and epistemology,

which can directly inform the design of transparent and explainable AI architectures [5]. Similarly, Vedic Mathematics offers unique principles for optimizing computational speed and efficiency, influencing core hardware design.[1] The relationship between AI and IKS is thus bidirectional, moving beyond simple preservation to mutual technological co-creation.

1.3. Academic and Institutional Contextualization

The institutional push for IKS inclusion through policies like the NEP demands that academic research establish a rigorous, quantifiable basis for these traditional systems. This requirement is underscored by existing criticism asserting that some IKS curricula may peddle pseudoscience, pseudohistory, or serve ideological goals [7]. To counter claims regarding the economic and professional disadvantage of IKS graduates, computational research must rely heavily on empirical validation—such as measured performance metrics, hardware efficiency gains, and structured evaluation benchmarks—to maintain academic integrity and demonstrate measurable, objective outcomes [7]. Therefore, the scholarly analysis of AI's role in IKS must focus on documented technical implementations and verifiable results.

2. Literature Review: Foundational Intersections of AI and Traditional Indian Disciplines

2.1. Computational Linguistics for Ancient Indian Texts

The application of AI to ancient Indian textual heritage faces unique linguistic challenges. Ancient languages, such as Sanskrit, exhibit high morphological complexity and low-resource status, demanding specialized techniques beyond those typically employed for modern, high-resource languages [9].

Early research demonstrated that standard machine learning methods could be adapted to these challenges. For instance, a bidirectional Recurrent Neural Network (RNN) model was successfully implemented for Sanskrit sentence boundary detection, achieving superior performance over a baseline Conditional Random Field (CRF) model by leveraging morphological and lexical features [9]. However, even these specialized models did not achieve sufficient accuracy for real-world segmentation without continuous human supervision, highlighting the persistent difficulty of ancient language NLP [9]. To manage the high volume and semantic density of philosophical and scientific content, Knowledge Graphs (KGs) have been identified as a necessary structural methodology [11]. KGs translate unstructured text into semantic triples, providing structured data representations that enable deeper reasoning and contextual understanding, which is critical for extracting and analyzing complex relationships embedded in texts like the *Vālmīki Rāmāyaṇa* [13]. The use of KGs bridges the gap between raw textual data and the structured data required for advanced AI systems.

2.2. Influence of Indian Formal Logic on AI Architecture

The Nyāya school of Indian philosophy is centered on logic, reasoning, and epistemology, formalizing means of valid knowledge (*pramāṇa*), including perception and rigorous inference (*anumāna*) [5]. This structured approach to logical reasoning is not merely a historical curiosity but offers a foundational framework for modern AI development, particularly in the realm of Explainable AI (XAI).

Nyāya's emphasis on sound, justifiable logic directly addresses the "black-box" problem prevalent in many modern machine learning models. By adopting Nyāya's principles of inference, decision-making algorithms can improve transparency and explainability, ensuring that AI predictions are grounded in reasonable, auditable steps rather than relying solely on opaque statistical correlations [5]. This theoretical contribution from IKS moves the relationship beyond simple data consumption to architectural co-creation, aligning the need for computational sophistication with the mandate for ethical, transparent AI systems in high-stakes application domains like finance and healthcare [15].

2.3. Traditional Medicine, Simulation, and Benchmarking

Ayurveda, as a traditional system of medicine, presents unique integration challenges for AI. It requires comprehension of profound philosophical foundations, such as *Tridosha* theory (Vata, Pitta, Kapha) and *Panchamahabhuta* (five elements), necessitating deep conceptual understanding rather than simple factual retrieval [3]. Diagnosis involves synthesizing information across multiple domains, including constitutional analysis (*Prakriti-Vikriti*) and lifestyle factors [3]. Educational technology has shown promise in addressing clinical skill gaps. The AyurSIM platform successfully implemented virtual patient simulation, using interactive cases aligned with standardized Ayurvedic protocols to provide culturally responsive, experiential learning, achieving a "good" usability score (77.08 on the SUS scale) among diverse participants [16]. Crucially, the BhashaBench-Ayur initiative represents a paradigm shift by introducing India's first comprehensive benchmark specifically designed to evaluate AI models on traditional Ayurvedic knowledge [3]. This benchmark provides an essential tool for measuring AI performance based on domain-specific, culturally authentic criteria, moving the assessment beyond mere linguistic fluency toward measuring conceptual comprehension of traditional concepts [3].

3. Methodology: A Framework for IKS Data Acquisition and AI Modeling

3.1. Methodologies for Data Curation and Standardization

The primary technical barrier to robust AI deployment in IKS is the scarcity and fragmentation of high-quality, standardized data [4]. Ancient manuscripts are often incomplete or lack standardization, complicating their seamless integration into unified AI systems [4].

To mitigate this challenge, the methodology relies on systematic, distributed annotation and repository development. Collaborative, web-based tools, exemplified by Sangrahaka and Antarlekhaka, are deployed to support the distributed creation of structured datasets [13]. This systematic process generates essential data for fundamental NLP tasks, such as sentence boundary detection, Named Entity Recognition, and action graph construction, by annotating core texts like the *Vālmīki Rāmāyaṇa* [13]. This iterative approach is designed to overcome fragmentation by constructing comprehensive, interlinked knowledge repositories necessary for subsequent AI modeling.

3.2. Technical Modeling Paradigms

The heterogeneity of IKS mandates the application of multiple, specialized AI paradigms, tailored to the structural logic of each domain.

- **Knowledge Graph (KG) Construction and NLP:** KGs provide the crucial semantic representation layer for IKS textual content [12]. They transform unstructured textual data—the core repository of traditional systems—into structured semantic triples, which facilitates deep reasoning necessary for complex systems like Ayurveda and philosophical texts [12].
- **Graph Machine Learning (GML) for Spatial Systems:** For Vastu Shastra, an architectural science based on spatial and relational guidelines [2], GML provides a conceptually aligned modeling approach. Architectural floor plans are represented as graphs, where rooms are nodes and their properties (e.g., name, orientation) are node attributes. Graph Classification models are trained using labeled datasets of compliant and non-compliant floor plans, formalizing traditional spatial principles into quantitative design metrics [2].
- **Computational Hardware Integration:** For domains centered on algorithmic efficiency, such as Vedic Mathematics, the methodology includes implementation at the hardware level. For instance, a 64-bit Arithmetic Logic Unit (ALU) has been designed and synthesized using Verilog HDL, based on Vedic Sutras, targeting improved performance and reduced delays in computation [1].

The integration modalities across these diverse IKS domains are summarized below:

Table 1: Summary of AI Implementation Modalities across Indian Knowledge System Domains

IKS Domain	Primary AI Paradigm	Computational Objective	Key Source/Methodology	Significance
Ayurveda (Medicine)	LLMs, Simulation, KG	Diagnosis, Knowledge Retrieval, Clinical Skill Development	BhashaBench-Ayur, AyurSIM platform [3]	Tests conceptual depth and addresses clinical education gaps.
Sanskrit/Textual Heritage	NLP, Knowledge Graphs (KGs)	Digital Preservation, Semantic Extraction (NER, Co-reference)	Bidirectional RNNs, Distributed annotation tools [9]	Overcomes low-resource and ancient language challenges through structured data creation.
Nyāya (Logic/Epistemology)	Explainable AI (XAI), Decision Systems	Transparent Inference, Decision Justification	Application of *Anumāna* (Inference) and *Pramāṇas* [5]	IKS contribution to AI theory, enhancing trust and auditability.
Vedic Mathematics	Hardware Acceleration, Quantum Algorithms	Computational Optimization, Reduced Time Complexity	64-bit ALU Implementation, Quantum Gate Simplification [1]	Provides empirical efficiency gains at the computational core.
Vastu Shastra (Architecture)	Graph Machine Learning (GML)	Design Compliance, Optimization, Personalized Recommendations	Graph Classification of Floor Plans [2]	Formalizes qualitative spatial principles into quantitative design metrics.

3.3. Validation and Ethical Frameworks

Validation of AI applications in IKS must rely on both technical metrics and cultural relevance. Technical success is measured by empirical performance against established domain benchmarks (e.g., BhashaBench-Ayur) and quantified gains in efficiency (e.g., reduced delay in hardware) [1].

Crucially, given that much of IKS is considered communal heritage, the integration process demands preemptive ethical planning [4]. Before large-scale digitization and commercialization, clear guidelines must be established to protect the interests and intellectual property rights (IPR) of indigenous communities [4]. This cultural sensitivity must also be integrated into the validation loop, requiring domain experts (such as Ayurveda practitioners or historians) to assess model outputs for philosophical depth and contextual soundness, thereby preventing superficial or incorrect interpretations of complex knowledge systems [3].

4. Results and Analysis: Operationalizing AI in Select IKS Domains

4.1. Performance Analysis in Traditional Medicine (Ayurveda)

The evaluation of state-of-the-art Large Language Models (LLMs) on Ayurvedic knowledge using the BhashaBench-Ayur standard revealed significant capabilities in structured information processing but profound limitations in integrative reasoning. The top-performing models, such as Qwen3-235B and DeepSeek-v3, achieved an overall accuracy of approximately 57–58% [3]. Analysis of the performance distribution indicates that AI systems excel in domains involving structured retrieval and pattern matching. Accuracy was notably high (over 80%) in *Roga Vigyana* (Diagnostics and Pathology) and Research & Statistics [3]. This suggests that AI is highly effective at retrieving discrete, factual, and standardized knowledge points. However, performance dropped significantly in areas requiring complex, integrative, and conceptual understanding. Accuracy levels fell to between 49% and 55% for domains such as *Dravyaguna* (Pharmacology and Therapeutics) and *Panchakarma* (Detoxification and Rejuvenation) [3]. Furthermore, performance on "Hard Questions"—those demanding sophisticated analysis and multi-step traditional logic—averaged only 46% [3].

Table 2: Comparative Performance Analysis of AI in Ayurveda (Based on BhashaBench-Ayur)

Ayurveda Domain Cluster	Primary Function	Observed Accuracy Range (Top Models)	Inferred AI Strength/Limitation	Source
Roga Vigyana (Diagnostics) & Statistics	Factual Recall, Pattern Matching	80%+	Strong performance; ability to retrieve structured, isolated facts.	3
Administration, Public Health	Application of Standard Protocols	60–75%	Moderate performance; handles defined rule-sets adequately.	3
Dravyaguna (Pharmacology) & Panchakarma	Integrative Reasoning, Complex Formulation	49–55%	Significant limitation; difficulty with multi-variable, conceptual, and holistic traditional logic.	3
Advanced/Hard Questions	Sophisticated Analysis,	46% (Average Top	Fails to apply complex traditional reasoning patterns.	3

	Advanced Logic	Performance)		

4.2. Computational Efficiency via Vedic Mathematics

The application of Vedic Mathematics Sutras provides concrete, quantifiable evidence of IKS contributing directly to modern computational efficiency. Research confirmed the successful implementation and synthesis of a 64-bit Arithmetic Logic Unit (ALU) based on these Sutras [1]. This implementation, designed with Verilog HDL, demonstrated verifiable performance improvements, specifically through reduced delays, and included power optimization techniques such as power gating [1]. Beyond current hardware, the theoretical potential of Vedic algorithms extends to next-generation computing. The analytical integration of Vedic Mathematics principles suggests they can simplify quantum gate computations, thereby reducing the time complexity required for advanced quantum AI models and optimizing critical algorithms such as Shor's and Grover's algorithms [10]. This empirical success establishes Vedic Mathematics not merely as a historical discipline but as a vital source of algorithmic innovation capable of impacting high-performance and energy-efficient computing [1].

4.3. Spatial Intelligence and Heritage Compliance (Vastu Shastra)

In the domain of Vastu Shastra, Graph Machine Learning (GML) has been successfully applied to formalize architectural compliance. By representing floor plans as relational graphs, researchers trained a graph classification model using a labeled dataset of compliant and non-compliant plans [2]. The resulting model achieved a reasonable initial accuracy of 77% in predicting compliance with Vastu guidelines [1].

Further applications in this field integrate Vastu principles with other traditional knowledge, such as astrological charts, offering personalized, energy-aligned recommendations for architectural design [17]. This synthesis of spatial analysis and personalized metrics demonstrates AI's capacity to formalize qualitative, complex IKS requirements into actionable, quantitative design parameters for the real estate and construction sectors [17].

5.3. Future Research Directions

Future research must prioritize expanding the scope and complexity of AI applications in IKS. This involves developing multilingual and multimodal AI techniques to handle the diversity of ancient scripts (e.g., Brahmi, Indus) and the various physical media upon which texts were written [9]. The observed performance drop in AI models when evaluated on traditional concepts presented in indigenous languages, such as Hindi [3], necessitates specialized attention to multilingual NLP methodologies that preserve conceptual integrity.

Furthermore, research should focus on scaling the success found in Vedic Mathematics and Nyāya logic into commercial and industrial applications, ensuring that IKS contributions are measurable not only in academic terms but also in economic and technological impact, aligning directly with the goals of national education and development policies [6].

6. Conclusion

Artificial Intelligence is fundamentally necessary for the sustainable preservation, computational modeling, and modern revitalization of the Indian Knowledge System. The research validates IKS not merely as a subject for digital archival, but as a proactive source of algorithmic innovation, demonstrated by the empirical efficiency gains delivered by Vedic mathematics in high-speed hardware [1]. However, the analysis underscores that AI's engagement with IKS remains immature in domains requiring deep, integrative, and conceptual understanding, such as traditional pharmacology [3]. The trajectory toward successful and scalable integration is predicated on addressing systemic, non-technical challenges. Overcoming pervasive data scarcity and fragmentation [4], ensuring continuous, rigorous scientific validation through domain-specific benchmarks, and most critically, establishing explicit ethical and legal policy frameworks to protect communal heritage and prevent the exploitation of indigenous knowledge are mandatory steps for achieving an ethical and effective computational synthesis of the *Bhāratīya Jñāna Paramparā*. Future research must converge toward hybrid AI architectures that leverage structured IKS logic to bridge the gap between AI's technical capacity and the philosophical depth required for true knowledge integration.

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