A Śāstrīya Framework for the Adaptation of the Foundational Principles of Classical Indian Dance and Theatre through AI and Machine Learning

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Abstract

This study proposes a novel Śāstrīya framework for adapting classical Indian dance and theatre into artificial intelligence (AI), machine learning (ML), and virtual production systems, addressing the urgent need to preserve and recontextualise traditional arts in the digital age. Grounded in Bharata's Nāṭyaśāstra and Abhinavagupta's Abhinavabhāratī, the research synthesises textual hermeneutics, paramparā praxis, and technical experimentation through an interdisciplinary methodology. Textual analysis computationally encodes śāstric principles, rasa-bhāva theory, abhinaya codification, and nāṭya-dharmī/lokadharmī dynamics into machine-readable formats (TEI XML, graph databases) to train AI models. At the same time, ethnographic inquiry draws on a decade of training under Śrī Piyāl Bhaṭṭācārya, incorporating case studies with practitioners to reconcile tacit performance knowledge with algorithmic logic. Leveraging the author's dual expertise as a VFX line producer and digital transformation consultant, applied experiments deploy markerless motion capture (Intel RealSense), neural radiance fields (NeRF), and generative AI (GPT-4/RAG) to prototype tools for śāstric-aligned choreography, virtual maṇḍapas (Unreal Engine), and AI-driven pedagogy. Ethical engineering prioritises cultural fidelity: crowdsourced datasets of mudrās and karanas mitigate Western-centric biases, while retroreflective costume threads and guru-śiṣya validation councils ensure technologies enhance, rather than erode, traditional aesthetics. To validate this approach, we propose employing dual metrics, comprising primarily śāstric peer review (e.g., abhinaya sequence compliance) followed by biometric audience testing (EEG, gaze tracking)—to quantify emotional resonance (rasa) in digital versus live performances. The intention behind this proposed framework is to offer a bridge between Indological scholarship, performing arts paramparā, and AI engineering, creating a scalable global cultural heritage preservation model by demonstrating how śāstric rigour can guide ethical, technological integration without compromising artistic sanctity. The study also suggests a replicable blueprint to utilise modern technological advancements as a digital upavīṇā, a supportive, non-invasive tool, to make tradition and the accelerating techno-cultural shifts go hand in hand.

Keywords: Virtual Reality, Indian Performing Arts, Artificial Intelligence, Natyashastra, Machine Learning

Introduction: Contextualising Nāṭyaśāstra in the Digital Age

This research was conducted during a period when the world was far from tranquil. Instead, it was a period marked by the turmoil of two devastating conflicts (Russia-Ukraine and Israel-Palestine) while several nations grappled with surging inflation, and others teetered on the brink of economic collapse. Climate change and pollution in major cities have reached critical levels, while market volatility, fragile security frameworks, and uncertain governmental policies have further exacerbated global instability.[1] Even today, South Asia's socio-economic equilibrium is far from secure. While growth projections appear robust, underlying vulnerabilities—ranging from climate risks to institutional weaknesses- pose existential threats. As the World Bank argues, the region needs a 'new playbook' combining domestic reforms, regional cooperation, and agile crisis responses to avert prolonged instability[2,3,4]

The three industrial revolutions are well-documented phenomena: the first marked by the rise of the factory

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system in the eighteenth century in Europe, the second by the advent of steam engines and electricity, and the third by the emergence of computers and the internet. Today, we are witnesses to the fourth industrial revolution, characterised by advancements in robotics, 3D printing, data analytics, the Internet of Things, blockchain technology, artificial intelligence, augmented reality, and virtual reality, innovations poised to redefine our very perception of reality.[5]

Given this context, the PESTLE (political, economic, social, technological, legal, and environmental) environment around us is not very favourable for art to progress. Given this trend, speaking of sastra or the practice of traditional art forms and the approach for their digital transformation may seem not just unnecessary but an outright indulgence. But is that truly the case? Let us find the answer in the Natyasastra itself. According to the Nāṭyaśāstra's narrative, when society became overwhelmed by kāma (desire), krodha (anger), īrṣyā (jealousy), and lobha (greed)—consumed by grāmya-dharma (base tendencies), Indra approached Brahmā requesting nāṭya to restore harmony and preserve Vedic knowledge. This narrative reminds us not only of the role of art in entertainment but also of its inherent sense of responsibility. Citing Śaṅkarācārya's bhāṣya on the Bṛhadāraṇyakopaniṣad, Śatāvadhānī Dr R. Ganesh observes that a śāstra primarily serves as a reminder rather than an enforcer of actions. It is not necessarily a source of creativity or direct inspiration, but it ensures adherence to a time-tested framework, preventing deviation from established principles.[6] In chapter 25 of the Nāṭyaśāstra, Bharata also suggested that strict reliance on scriptural authority falls short of fully capturing the interplay of inner emotions and outward actions in the static and dynamic realms of existence. Instead, the wide variety of natural dispositions, with each possessing its unique temperament, has given rise to the refined art of drama.[7]

This demonstrates that artistic practice cannot exist in isolation from its temporal and social context. Thus, in this third decade of the twenty-first century, where the modes of artistic engagement are constantly transforming, the central question within the performing arts domain is: what should the artist's role be? This question raises several subordinate questions, such as, Are we witnessing the emergence of new creative media, new economic models for art, new creative processes, and new ways to experience art, where the communal experience of art is increasingly replaced by a personalised engagement, all under the guise of convenience.[8] Is it enough to merely react to the changes unfolding before us, or should we treat these transformations as temporal markers, reinterpreting our understanding of contemporaneity through them? How should we conceive of art and its necessity, the modes of communication, and the framework for artistic practice and education? And finally, how can we integrate the wisdom of Śāstra into technology while embedding technology within the *Paramparā* (lineage) and *Sampradāya* (tradition) of traditional Indian arts?

Research Methodology

This study employs a Śāstrīya framework integrating textual analysis, ethnographic inquiry, and applied AI experimentation, drawing from my expertise in traditional theatre, VFX production, and digital transformation consulting.

Textual Analysis – Examines Bharata's Nāꣳyaśāstra (with Abhinavagupta's commentary Abhinavabhāratī).

Ethnographic Inquiry – Incorporates insights from my decade-long experience in Indian theatre and scholarly interpretations from Śrī Piyal Bhattacharya, emphasising bhāva-rasa theory, abhinaya codification, and the nāꣳya-dharmī vs lokadharmī dichotomy, alongside case studies of practitioners, choreographers, and AI researchers.

AI, ML and Virtual Production Experimentation – Leverages my expertise as a Compositing Department Line Producer and digital transformation consultant to explore AI-driven motion capture, pose estimation, and generative choreography while addressing ethical and preservation concerns.

Artificial Neural Network, AI and Machine Learning

In 2022, with the launch of platforms like Midjourney and OpenAI's ChatGPT, public curiosity about generative artificial intelligence was reignited. However, the application of AI is not as recent as it may seem. Google has been prominently deploying AI technologies since around 2015 in consumer-facing applications.[9] Even before 2020, AI was extensively used in applications such as spam filtering in emails, facial recognition in security systems, personalised product recommendations on online shopping platforms, fraud detection in financial transactions, voice assistants like Siri and Alexa, self-driving car navigation systems, medical image analysis for disease diagnosis, machine translation tools, and advanced robotics in manufacturing processes. It leveraged machine learning to analyse large datasets and make automated decisions across various sectors.[10]

Rather than perceiving intelligence and artificial intelligence solely through machine learning and science, examining them from the perspective of literature and the arts would be more insightful for artists. Let us consider, for instance, how Kṛṣṇadvaipāyana Vyāsa composed the Jaya, which later in the Gupta Period became known as the Mahābhārata. This act of composition was not

spontaneous and required extensive preparation. He had to acquire proficiency in language, philosophy, Vedic studies, and Purāṇic knowledge (considering that Purānas existed before his time). Additionally, by relying upon his lived experiences, a century's worth of personal memory, and the vast reservoir of civilizational memory accumulated over generations, along with his insights and interpretative experiences, he ultimately composed the Jaya, which later became one of the most revered epics of human civilisation.

The intelligence through which Vyāsa accomplished this task is what we recognise as human intelligence. The Mahābhārata stands as a distinguished and extraordinary example of human intellectual and creative capability. Now, let us assume we create a generative AI model named 'Vyāsa AI' to compose a new version of the Mahābhārata. We would need to feed this model with an extensive corpus of knowledge, texts, and diverse philosophical perspectives. Additionally, we would refine it using elements of human memory and the nuanced emotional and aesthetic dimensions that constitute civilizational memory. Since human cognition follows specific patterns, and thus, we would be designing a thought process within this machine, ensuring that the content it generates carries a semblance of original insight and experience. However, since this thought process and its resulting combinations are artificially constructed, externally programmed, and machine-driven, their intelligence must be considered artificial.

Machine learning is a branch of artificial intelligence that enables systems to learn and improve performance through data analysis, using various techniques including neural networks and deep learning algorithms. In practice, this means that computer systems can continually refine their performance as they gather more "experience" from the data they process, and their capabilities can be enhanced further when they are supplied with more extensive and more excessive and diverse datasets.[11]

Artificial Neural Networks (ANNs) are computing systems inspired by the human brain, composed of interconnected nodes (neurons) arranged in layers. They learn by adjusting connection strengths (weights) based on input data, allowing them to recognise patterns and make decisions. But how is the art world leveraging the benefits from it? While some performing artists see AI as a tool that enhances their creative possibilities[12], others critically examine its implications and biases.[13] AI-driven systems such as deep-learning choreography models, generative music compositions, and interactive stage technologies operate under supervised learning[14], meaning they generate performances based on predefined patterns and human-labelled data. However, some artists are drawn to unsupervised learning models[15], which operate more autonomously, creating unexpected interpretations beyond direct human influence.

Let us explore some of the AI-driven technologies and projects that are already shaping the performing arts. For instance, Wayne McGregor, a choreographer with the Royal Ballet in London, teamed up with Google to develop a system known as Living Archive[16] by providing training to an ANN on his 25 years of choreographies to generate stick-figure projections that suggest new dance movements. As the dancers perform, the algorithm continuously responds to their movements by suggesting additional positions based on what it observes.[17] Moreover, as seen in projects like Discrete Figures[18], AI is already stepping onto the stage where real-time motion capture integrates dancers' movements with algorithmically generated visuals. Projects like Lumin AI[19], a collaborative dance composition between humans and AI presented by Georgia Institute of Technology & Kennesaw State University, also explore these synergies, redefining the relationship between human performers and machines and expanding dance beyond traditional physical limitations. Training methodologies and tools like Dancing Inside[20] provide remote learning with AI-driven feedback, pushing the conventional boundaries of choreography and dance training methodologies.

In theatre, AI's role has already extended from scriptwriting to stage design and even real-time audience interaction. Projects like Algorithmic Theatre[21] and The Singularity Play[22] explored AI's capacity to co-write scripts, raising questions about creativity and authorship. Performances such as A&I by Orange Grove Dance[23] demonstrate how AI reacts to human input, altering lighting, sound, and movement to craft immersive, ever-evolving theatrical experiences[24]. Meanwhile, AI-driven tools such as Artificial Intelligence Director (AID), which experiments with spatial positioning in virtual theatre environments, also provide a fresh perspective in the domain.[25]

Monitoring the latest patent filings offers a proactive means to anticipate emerging trends and gauge technological progress. Shen Yun Performing Arts secured a patent for an animated projection backdrop and stage interaction system that lets performers interact with dynamic digital environments, effectively expanding the stage and creating immersive experiences.[26] In 2015, Shmuel Ur filed a patent for a body-worn device that provides tactile feedback during social dancing, simulating partner cues to enable safe and interactive dance simulations.[27] Sphere Entertainment recently secured patents for immersive AR/VR systems that allow for real-time event simulation and multi-user collaboration in a virtual reality environment, enabling performers to rehearse and create interactive stage

experiences.[28] Additionally, patents such as the '3D real-time scene interaction system based on metaverse VR/AR and AI technology' (CN114327055A) demonstrate how innovative methods are being developed to capture and render dynamic, lifelike digital environments, further blending physical and virtual realms in live performances.[29]

The Foundation of Traditional Indian Arts

Many technical practitioners in Creative AI focus on replicating and extending existing artistic styles using data-driven techniques rather than engaging with the more profound philosophical questions that traditionally surround art. Their primary goal is to develop algorithms that can learn from established aesthetics and generate similar or slightly divergent outputs, emphasising technical performance and reproducibility.[30] Adapting traditional Indian performing arts for Creative Algorithmic Intelligence and Machine Learning requires not merely transforming form, content, and communication methods, but fundamentally reinterpreting the underlying philosophy. At the very core of Indian performing arts, be it nāṭya, gīta, nṛtya or vādya, lies nāda, from which all art is born. Nāda manifests in two forms: one anāhata and the other āhata. Within anāhata nāda resides the latent power to purify the citta (mind and intellect), enriching it. Conversely, āhata nāda conceals the potent capacity to mesmerise the phenomenal world, enabling all living beings to savour a bliss of liberation—that feeling of being emancipated from this ephemeral existence. Both these nādas originate from the śarīra-piṇḍa, within which, according to the śāstras, lie six cakras and fourteen nāḍīs.[31] It becomes evident, therefore, that for any form of Indian traditional artistic practice, the primary requisite, as delineated by the śāstra, is deha (body). Whether one practices Bharatanāṭyaṁ, Kathak or Mārgīya Nāṭya, deha remains paramount. A robot lacks such a deha, and no AI, AR, or VR can manufacture one. However, for an individual endowed with a deha and the capacity for bhāvana, these technologies can indeed serve to train, enhance their skills, and augment their cognition, albeit without the immediate corrective guidance of an in-person teacher. Additionally, for students who do not possess the physicality of a South Asian physique but wish to engage in South Asian performing arts, such technologies could prove immensely beneficial.

In the confluence of knowledge and technology, a certain magic becomes possible: that which, hitherto, we might have dismissed as a mere flight of fancy can be actualised, and indeed, entirely new creations may emerge. Given that Indian Dance & Drama traditionally falls into two categories, mārgīya and deśī, we might even propose a new form of art in our discussion: one that is categorically of a third kind, genuinely digital, and not merely a pre-recorded rendition of a staged performance.

Adapting These Foundational Principles for a Virtual and Augmented Future

To digitise the knowledge of the Nāṭyaśāstra, we must first establish the core technical pillars. This begins with the creation of a user-friendly digital resource for Bharata's Nāṭyaśāstra, incorporating Abhinavagupta's commentary and modern bhāṣyas as its backbone. Authoritative manuscripts will be meticulously assembled and encoded using the Text Encoding Initiative (TEI) XML standard, a specialised markup language for humanities texts. Each sūtra, along with its corresponding explanatory notes, will be systematically tagged with semantic metadata[32] (e.g., , <note type="commentary">), enabling granular cross-referencing and analysis. These digital files will be stored in a version-controlled repository like GitHub to ensure robust tracking of revisions and collaborative integrity.

Subsequently, a modern JAM stack architecture[33] will be employed, combining a headless CMS like Strapi for content management with a React/Next.js frontend for interactivity. This will allow the creation of a fast, responsive website that faithfully reflects the traditional structure of the text while incorporating advanced features such as dynamic search, cross-referencing, and customisable transliteration options. To further enhance this digital resource, an AI chatbot will be integrated, capable of answering questions related to the Nāṭyaśāstra while providing well-reasoned explanations and verifiable citations.

The development of such an AI chatbot requires the digitisation of the key texts and commentaries of Indian Knowledge Systems, such as the Nāṭyaśāstra, Abhinavabhāratī, the Vedas and their commentaries, as well as the darśanas and tantras (we can partner with institutions for textual resources, such as IGNCA and Banaras Hindu University, SNA)—converting them into structured digital formats like TEI XML. This will enable the tagging and linking of specific parts (e.g., sūtras, commentaries, and definitions) with appropriate metadata and source citations. The corpus will then be cleaned and organised into a graph database (e.g., Neo4j) to facilitate efficient retrieval and cross-referencing.

The AI chatbot can be built by fine-tuning a domain-specific pre-trained language model, like AI4Bharat's models[34] and using machine learning libraries like Hugging Face's Transformers[35] or PyTorch[36]. A RAG or retrieval-augmented generation[37]. The approach can be implemented and orchestrated through frameworks like

LangChain[38] or LlamaIndex, ensuring that the system generates contextually relevant responses and retrieves supporting passages along with their citations. This methodology, similar to that employed in projects like BharatGPT[39]will be integrated into the website via a custom chat interface that displays both responses and inline citations or hoverable footnotes for transparency. To ensure authenticity and build trust, the system will include a confidence score for each AI-generated answer and automatically append citations to every response. Additionally, a user feedback loop will be incorporated for continuous refinement, while contextual disclaimers[40] may be added to address potential oversimplifications of cultural context.

The website will be further enriched by adding a visual archive illustrating traditional performance elements, allowing users to observe how ancient dance and acting techniques were performed. AI and machine learning applications will be integrated to analyse digitised performances, providing annotations and explanations for movements, gestures, and postures. To address the challenge of training custom pose estimation models[41] (e.g., OpenPose) without labelled datasets of Indian classical gestures, we can partner with institutions, such as Chidakasa Kalalaya[42] and Kalakshetra Foundation[43] to crowdsource labelled performance datasets. Transfer learning will fine-tune pre-trained models like MediaPipe Holistic on smaller domain-specific datasets, ensuring accuracy and relevance.

These technologies will also automate content tagging and metadata generation by analysing video content to generate tags, categories, and descriptions; detect scene changes and identify key moments; recognise objects, faces, and locations within videos; generate subtitles and translations; create content timestamps; and produce automated thumbnail previews. To mitigate the risk of inaccuracies in automated metadata generation (e.g., mislabeling mudrās), a human-in-the-loop validation system will be deployed, enabling scholars to verify AI-generated tags through a crowdsourcing interface. Additionally, IIIF (International Image Interoperability Framework) standards will be adopted for media assets to ensure cross-archive compatibility and interoperability.

To incorporate AI-driven video analysis, a flexible API gateway will be developed to dynamically handle requests across multiple providers like Google, AWS, and Azure. This will enable automated tagging, scene detection, object recognition, and metadata generation while ensuring scalability and adaptability. For a more tailored approach to Nāṭyaśāstra-based performances, custom AI models will be trained using TensorFlow or PyTorch for gesture recognition, OpenPose for human pose estimation, YOLO for object detection, and MediaPipe for lightweight, real-time applications. An API-driven pipeline will allow authorised users to upload performance videos, process them through AI for annotations, and store structured metadata in a searchable database. This will enable dynamic overlays where users can interact with annotated gestures and access corresponding references from the Nāṭyaśāstra and Abhinavabhāratī.

To enhance accessibility, a searchable video library will be built with real-time augmented reality (AR) annotations and an intuitive user interface that highlights key scenes and auto-generates descriptions. A graph database like Neo4j will manage cross-referencing between the Nāṭyaśāstra, temple sculptures, and Abhinavabhāratī, enabling intuitive connections between gestures, texts, and visual representations. AR integration will go beyond simple annotations by using open-source WebAR frameworks like A-Frame or AR.js, allowing users to experience 3D reconstructions of poses and movements in their own space. For advanced 3D reconstructions, Unity WebGL builds with WebXR will be deployed. For efficient video streaming and caching, WebRTC or DASH will be implemented for adaptive bitrate streaming, while cloud storage solutions such as AWS S3 or Google Cloud Storage, combined with a CDN like Cloudflare, will ensure smooth playback.

Once the website is operational, integrating a Virtual Reality (VR) to recreate classical Sanskrit performance spaces with architectural precision and dynamic interactivity, guided by the principles outlined in Chapter Two of the Nāṭyaśāstra, may become helpful for the users. The text describes three distinct nāṭya-maṇḍapas, Vikṛṣṭa (rectangular, 108 cubits), Caturaśra (square, 64 cubits), and Tryaśra (triangular, 32 cubits), each meticulously designed with functional components such as the Raṅgapīṭha (stage floor), Raṅgaśīrṣa (raised stage top), Nepathya-gṛha (backstage area), and auxiliary elements like Mattavāraṇī and Yavanikā, which structure performances while influencing acoustics and audience engagement. By digitising these architectural elements through 3D modelling and integrating them into modern VR engines such as Unreal Engine or Unity, we can reconstruct ancient performance spaces with spatial accuracy and immersive interactivity.

To simulate the dynamic acoustics and physics described in the Nāṭyaśāstra, spatial audio engines like Resonance Audio and physics engines like NVIDIA PhysX will be integrated into the VR environment. Scholarly annotations will be added as clickable elements (e.g., pillars explaining maṇḍapa design rules from Chapter 2), enhancing the educational value of the experience. The reconstructed performance spaces will allow users to experience the interplay between stage design, actor

movement, and audience perspective. Interactive features will enable users to navigate between different theatre types and explore how alterations in spatial configuration affect acoustics and visual sightlines, providing a tangible demonstration of the Nāṭyaśāstra's principles in action. This immersive approach will enhance scholarly understanding of ancient dramaturgy and democratise access to cultural heritage, bridging classical architectural treatises with contemporary digital visualisation techniques.

We can also incorporate our hypothetical AI tool, Vyāsa AI, by developing it and feeding it principles drawn from the Gati chapters, Kakṣyabibhāga, and the tenets of samānyābhinaya, among other theatrical elements. This will enable the construction of a comprehensive 'kramadīpikā' (methodology) for the 'aṭṭaprakāram' (text or rūpaka) such as Vikramorvaśīya (by Kālidāsa) and Mudrārākṣasa (by Viśākhadatta), much like the tradition found in Kūṭiyāṭṭam, thereby assisting performers and directors in improvising more effectively.

Finally, the site will be deployed on a reliable hosting service like AWS Amplify or Google Firebase, ensuring serverless scalability for video processing and VR integrations. Cloudflare R2 will be used for cost-efficient video storage and streaming, while edge caching will ensure global, low-latency access to text and resources. Community feedback mechanisms will be integrated through platforms like Hypothesis, which allows for collaborative annotation of texts and a GitHub Issues-style forum for scholarly discussions and corrections. To preserve digitised manuscripts as FAIR (Findable, Accessible, Interoperable, Reusable) data resources, they will be published on Zenodo or IIIF repositories with CC-BY-SA licenses, accompanied by Dublin Core metadata for all assets.

By combining pre-trained AI models with custom-trained systems, we can create an intelligent, interactive archive that brings the performative and architectural aspects of the Nāṭyaśāstra to life, making the rich heritage of Indian Knowledge Systems accessible to both scholars and non-technical users alike. This integrated approach, developed in collaboration with traditional practitioners and institutions, ensures cultural sensitivity, academic rigour, and technological innovation.

The Virtual Stage: Understanding the Pipeline of Virtual Production for Performing Arts Adaptation

"Building upon this foundation, we propose a third category beyond the Mārga (classical, rule-based) and the Deśī (regional, area-based), which can be defined as a Virtual or Digital Nāṭya—a form distinct in its interactivity, immersive spatial design, and hybrid media integration. Unlike traditional classifications, Digital Nāṭya reimagines the raṅga (performance space) as a dynamic, responsive environment. Here, audiences engage through VR/AR while live performers interact with CGI, motion capture, and real-time rendering. This synthesis transcends archival or pedagogical applications, offering a fundamentally new medium for applying the Nāṭyaśāstra's principles.

In Chapter VI of the Nāṭyaśāstra, Bharata Muni identifies eleven components of the nāṭya saṃgraha:

> "Rasa bhāvahyabhinaya dharmī vṛtti pravṛttayaḥ
> Siddhiḥ svarāstathātodyaṁ gānaṁ raṅgaśca saṅgrahaḥ"
> —(NS 6:10)

Here, abhinaya (expression), svara (melody), atodya (instrumentation), and gāna (ensemble) remain the sensory media, while rasa (aesthetic emotion), bhāva (mood), dharmī (stylisation), vṛtti (dramatic modes), and pravṛtti (regional styles) form the architectural core. Siddhi—the performance's success—is measured by its emotional resonance, while the raṅga grounds the spatial and aesthetic context. Digital Nāṭya expands this framework: computer-generated raṅgas enable artists to perform within virtual environments, blending live action with real-time CGI—a technique refined in filmmaking but revolutionary for theatre.

The process begins with previsualisation, where the digital raṅga is conceptualised using tools like Unreal Engine for real-time rendering and Blender for 3D modelling. These platforms integrate Nāṭyaśāstra principles, such as the maṇḍapa stage design from Chapter 2, ensuring spatial aesthetics align with classical conventions. Lighting is calibrated through HDR and ray tracing in NVIDIA Omniverse, mirroring the natural acoustics of traditional stages, while dynamic environments adapt to reflect the vṛttis (dramatic modes).

For performance capture, artists wear traditional costumes unhindered by obstructive technology. Instead of inertial suits, depth-sensing cameras like Intel RealSense or Microsoft Azure Kinect track 3D skeletal movements via infrared sensors. AI-driven pose estimation tools like MediaPipe or OpenPose analyse RGB video feeds in real-time, inferring body movements even under layered fabrics—whether Kathakali's heavy skirts or Bharatanatyam's pleated sarees. To enhance precision without compromising āhārya (costume aesthetics), retroreflective threads are subtly woven into garments, detectable by infrared cameras yet invisible to the audience.

Critical to Abhinaya, facial expressions are captured through Neural Radiance Fields (NeRF), a volumetric multi-camera system that reconstructs 3D facial dynamics without markers. This preserves intricate makeup

like Kathakali's chutti (rigid facial adornments). Deep learning models, trained on classical Abhinaya datasets, decode subtle drishti (eye movements), bhru (eyebrow shifts), and *mukha* (lip gestures), mapping them onto digital avatars via tools like Apple ARKit.

Post-capture, dynamic cloth simulation in Marvellous Designer or Clo3D replicates the fluidity of traditional costumes—swirling angavastrams or jingling ghungroos, ensuring the digital raṅga responds authentically to fabric movement. Pre-calibration sessions with performers help machine learning models generalise karanas (movement units) across unpredictable live acts.

The immersive output extends beyond mere spectacle. VR experiences, built with Unity XR or Unreal's VR toolkit, allow audiences to navigate the raṅga spatially, viewing the performance from the actor's perspective or exploring the stage's symbolic architecture. Spatial audio via Resonance Audio replicates temple theatre acoustics, while AR overlays (powered by 8th Wall or AR.js) annotate gestures and costumes in real-time, offering multilingual scholarly insights. Crucially, these innovations adhere to ethical frameworks: collaborations with Kūṭiyāṭṭam artists and costume designers safeguard cultural authenticity, ensuring tracking threads or embroidery modifications respect śāstra-aligned symbolism.

Scalability is achieved through modular workflows. Python scripts and Unreal Blueprints automate repetitive tasks, while cloud rendering services like AWS Thinkbox handle large-scale processing. Version control via Perforce Helix ensures seamless asset management across global teams. Audience agency is central to this pipeline: biometric sensors and VR headset analytics measure emotional engagement (siddhi), while interactive features—live polls and gesture-triggered scene changes—transform spectators into co-creators, echoing Bharata's vision of rasa as a collective experience.

By threading Nāṭyaśāstra's tenets through virtual production, AI-enhanced abhinaya, responsive raṅgas, and ethical hybridity, Digital Nāṭya emerges not as a replacement but an evolution. It honours the śāstra's rigour while reimagining its loka (world), a stage unbound by physicality yet deeply rooted in cultural memory, where tradition and innovation coexist in symbiotic grace.

Towards a New Aesthetic Paradigm

Currently, comprehensive socio-economic ethical frameworks for AI experimentation and application remain underdeveloped. Nevertheless, AI development continues across multiple domains. On the contrary, one of the most pressing concerns today is the question of ownership over AI-generated content. Given that large language models such as GPTs have been trained on vast amounts of data and that AI art generators like Midjourney or DALL·E rely on extensive art databases, do these systems not infringe upon the copyright of original works? With these critical concerns in mind, we have proposed new applications in our discussion. These proposals are open to necessary modifications, and certain technological revolutions may render some of their core propositions obsolete even in the time between the writing and the publication of this article. Such is the inherent vulnerability of contemporary technological trends. Yet, this does not alter our fundamental needs or the philosophical stance of this article. While methodologies may evolve, the fundamental need to preserve and adapt cultural heritage through technology remains constant.

The application of Indian performing arts, rooted in the śāstric tradition, transcends the boundaries of time and space, a fact empirically validated through history. From the Vedic legends of the ṛṣis' curses leading to the descent of Bharata's sons to the mortal realm to Emperor Aśoka's decree prohibiting theatrical performances to the resilience of Indian classical arts in overcoming the dark ages following the Turkish invasions, the tradition has continually adapted and thrived in remarkable ways. The śāstras, today, have remained relevant through their dynamic reinterpretations and evolving applications. This process informs our AI, AR, VR, and machine learning approach. We must not forget that just as we employ AI, AR, VR, and machine learning to enhance our engagement with artistic traditions, these technologies simultaneously utilise our art forms for their advancement. I do not see this as a conflict in the progress of civilisation. However, due to capitalist imperatives, numerous dark voids exist within this integration, and navigating them consciously is no simple task. Yet, if artists and connoisseurs collectively employ AI, AR, VR, and machine learning with the finesse of a digital *upavīṇā* (a delicate accompaniment to the primary art), we may anticipate a future where tradition and innovation coexist in a harmonious equilibrium.

Notes

1. For an analysis of the global economic outlook and recession risks in 2023, see *Why a Global Recession Is Inevitable in 2023*, *The Economist*, November 18, 2022.
2. For insights into global economic trends and policy implications, see the World Bank Report, *World Bank Open Knowledge Repository*.
3. For an analysis of contemporary economic policy challenges from a southern perspective, see Navigating Today's Complex Economic Policy Triangle: A View from the South, *GÉOPOLITIQUE*, December 18, 2024.

4. For an overview of global economic prospects in 2025, see Global Economic Prospects – January 2025 Press Release, *World Bank*, January 16, 2025.
5. Kumar, K. J. (2004). Mass Communication in India: Fifth EditionJaico Publishing House. [Note: The preface offers an overview of the evolving landscape of mass communication in India, addressing its historical, cultural, and technological impacts on society]
6. For insights into the need of a śāstric framework, see Satāvadhāni Dr. R. Ganesh, *Prekṣaṇīyam: Essays on Indian Classical Dance and Theatre*, adapted into English with additional notes and supplementary content by Arjun Bharadwaj (Prekshaa Pratishtana, December 2022), 1.
7. For a reference to the 25th chapter of the *Nāṭyaśāstra*, see Nāṭyaśāstra Chapter 25, *Sanskrit Documents*.
   na ca śakyaṃ hi lokasya sthāvarasya carasya ca ।
   śāstreṇa nirṇayaṃ kartuṃ bhāvaceṣṭāvidhiṃ prati । NS. 25. 122 ।
   nānāśīlāḥ prakṛtayaḥ śīle nāṭyaṃ pratiṣṭhitatam ।
   tasmāllokapramāṇaṃ hi vijñeyaṃ nāṭyayoktṛbhiḥ । NS. 25. 123 ।
8. The shift from communal to personalised engagement in art can be observed when comparing the experience of watching a live theatre performance with viewing a movie on Netflix or other OTT platforms. While theatre offers a collective, immersive experience, streaming services provide individualised access, often diminishing the shared social interaction.
9. For an overview of how Google uses artificial intelligence in its search engine, see How Google Uses Artificial Intelligence in Google Search, Search Engine Land,
10. For an explanation of artificial intelligence and its applications in various sectors, see What Is Artificial Intelligence and How Is It Used? European Parliament,
11 . For an introduction to machine learning and its applications, see What Is Machine Learning? *Google Cloud*.
12. For an analysis of AI as a tool in the arts, see AI as a Tool in the Arts, Arts Management and Technology Laboratory, January 2020.
13. For an exploration of AI, celebrity clones, and digital intimacy in contemporary art, see Xanthe Dobbie's Future Sex/Love Sounds: AI, Video, and Celebrity Clones, The Guardian, August 30, 2024
14. Wayne McGregor's "Living Archive" is a good example of a Supervised learning model.
15. The cyclic Attribute-Conditioned Variational Autoencoder (AC-VAE) model described in the paper 'Choreographing the Digital Canvas: A Machine Learning Approach to Artistic Performance' (Peng, S., Ladenheim, K., Shrestha, S., & Fermüller, C. (2024). Choreographing the Digital Canvas: A Machine Learning Approach to Artistic Performance. arXiv preprint arXiv:2404.00054.) is an example of an unsupervised (or self-supervised) learning model. This model learns the underlying patterns of motion from raw motion capture data without needing explicit labels, and then uses these learned representations to generate new, creative 3D movements.
16. For an exploration of AI and dance through archival choreography, see Living Archive – Wayne McGregor, Google Experiments.
17. Studio Wayne McGregor, "Living Archive: Creating Choreography with Artificial Intelligence," *Arts & Culture Google*, accessed 8th February 2025,
18. For insights into Discrete Figures, a project exploring the intersection of technology and performing arts, see Discrete Figures, Rhizomatiks Research.
    For a visual explanation of the topic, see: YouTube
19. For a video on the topic, see: YouTube
20. Kang, J., Kang, C., Yoon, J. et al. Dancing on the inside: A qualitative study on online dance learning with teacher-AI cooperation. Educ Inf Technol 28, 12111–12141 (2023). https://doi.org/10.1007/s10639-023-11649-0
21. Miriam Felton-Dansky; The Algorithmic Spectator: Watching Annie Dorsen's Work. *TDR/The Drama Review* 2019; 63: 4 (244), 66–87. doi: https://doi.org/10.1162/dram_a_00875
22 For an exploration of AI's role in one of the most human art forms, see What Happens When AI Takes On One of the Most Human Art Forms?, Harvard Gazette, April 2023.
23 For insights into the intersection of AI and dance, see AI, Orange Grove Dance.
24 For a discussion on AI-generated theatrical performances, see Spellbinding Yet Unnerving: A Theatrical Performance Created by AI, BmoreArt, May 2024.
25. For a research perspective on autonomous agents and multiagent systems, see Proceedings of AAMAS 2013, International Foundation for Autonomous Agents and Multiagent Systems (IFAAMAS), 2013.
26. For insights into Shen Yun's patented animated projection and stage interaction technology, see Animated Projection Backdrop & Stage Interaction: A Shen Yun Patent, Shen Yun Performing Arts.
27. For notable patent innovations from 2021, see 2021 Patent Picks, World Intellectual Property Organization (WIPO).
28. For an analysis of patents related to the Las Vegas Sphere and Abu Dhabi's innovations, see Las Vegas Sphere & Abu Dhabi Patents, Parola Analytics.
29. For details on the patent CN114327055A, see Google Patents.
30. For a study on the impact of AI in the arts, see AI and the Arts, Oxford Internet Institute, March 2022.
31. For a better understanding of nāda and nāḍīs, refer to Chapter 5 of the critical edition, introduction, and English translation of Sangīta-darpanah, created by Gaurīśvara, edited by Arjun Bharadwaj, with Hindi translation by Sudarshan Muralidhara, and compilation and research by Sunil Sunkara (Kalāshram)
32. For an explanation of semantic metadata and its role in knowledge management, see *Semantic Metadata: The Metadata That Makes Knowledge Work*. *Ontotext*.
33. For an explanation of the benefits of JAMstack, see *Why JAMstack?*.
34. For AI tools related to Bharat, see *AI Tools*, *AI4Bharat*, Indian Institute of Technology Madras.

35. Hugging Face. (n.d.). *Fine-tune a pretrained model*. In *Transformers documentation*. Retrieved February 11, 2025, from https://huggingface.co/docs/transformers/main/en/training
36. For information on PyTorch, see *PyTorch*, *PyTorch*.
37. For an overview of retrieval-augmented generation, see *Retrieval-Augmented Generation*, *Google Cloud*.
38. For details on LangChain, see *LangChain*.
39. CoRover. (n.d.). *Conversational AI Chatbot - Structure and Architecture*. CoRover. Retrieved February 11, 2025, from https://corover.ai/architecture/
40. For example: This AI interpretation is a starting point; consult primary sources"
41. For an overview of the top pose estimation models of 2022, see *Top 9 Pose Estimation Models of 2022*, *Augmented Startups*.
42. For information on *Chidakash Kalalay*, see *Chidakash Kalalay*, *Wikipedia*
43. For details on Kalakshetra Foundation, see *Kalakshetra Foundation*.

References

2021 patent picks – Weird and wonderful. (n.d.). Patents. https://www.wipo.int/en/web/patents/2021_patent_picks

A&I | OrangeGrovedance. (n.d.). Orangegrovedance. https://www.orangegrovedance.com/a-i

Buckley, N. (2024, August 29). Ethically dubious or a creative gift? How artists are grappling with AI in their work. The Guardian. https://www.theguardian.com/artanddesign/article/2024/aug/30/xanthe-dobbie-futuer-sex-love-sounds-ai-video-celebrity-clones

CoRover. (n.d.). *Conversational AI Chatbot - Structure and Architecture*. CoRover. Retrieved February 11, 2025, from https://corover.ai/architecture/

Discrete Figures -ELEVENPLAY×Rhizomatiks Research× Kyle McDonald. (n.d.). Discrete Figures -ELEVENPLAY× Rhizomatiks Research×Kyle McDonald. https://research.rhizomatiks.com/s/works/discrete_figures/en/

Dwivedi, P. (2004). *Natyasastra of Sri Bharata Muni (I-IV)*. Sampurnanand Sanskrit Vishvavidyalaya.

Economic Development of the New South after the Washington Consensus - Groupe d'études géopolitiques. (2024, December 18). Groupe D'études Géopolitiques. https://geopolitique.eu/en/2024/12/18/navigating-todays-complex-economic-policy-triangle-a-view-from-the-south-en/

Felton-Dansky, M. (2019). The Algorithmic Spectator: Watching Annie Dorsen's work. TDR/the Drama Review, 63(4), 66–87. https://doi.org/10.1162/dram_a_00875

Ganesh, R. (2022). Prekṣaṇīyam: Essays on Indian Classical Dance and Theatre (B. Arjun, Ed.; A. Bharadwaj, Trans.; 2nd ed.) [English]. Prekshaa Pratishtana.

Gaurīśvara. (2022). *Sangīta-darpaṇaḥ* (A. Bharadwaj, Ed. & Trans.; S. Muralidhara, Hindi Trans.; S. Sunkara, Comp. & Research). Kalāshram

Harvard Gazette, & Harvard Gazette. (2023, November 9). What happens when computers take on one of the 'most human' art forms? Harvard Gazette. https://news.harvard.edu/gazette/story/2023/04/what-happens-when-ai-takes-on-one-of-most-human-art-forms/

Hugging Face. (n.d.). *Fine-tune a pretrained model*. In the *Transformers documentation*. Retrieved February 11, 2025, from https://huggingface.co/docs/transformers/main/en/training

Jordan, J. (2022, August 16). AI as a Tool in the Arts — AMT Lab @ CMU. AMT Lab @ CMU. https://amt-lab.org/blog/2020/1/ai-as-a-tool-in-the-arts

Kang, J., Kang, C., Yoon, J., Ji, H., Li, T., Moon, H., Ko, M., & Han, J. (2023). Dancing on the inside: A qualitative study on online dance learning with teacher-AI cooperation. Education and Information Technologies, 28(9), 12111–12141. https://doi.org/10.1007/s10639-023-11649-0

Kumar, K. J. (2020). Mass Communication in India, Fifth Edition. Jaico Publishing House.

Living Archive by Wayne McGregor by Wayne McGregor in collaboration with Artist in Residence at Google Arts & Culture Lab: Bastien Girschig - Experiments with Google. (n.d.). https://experiments.withgoogle.com/living-archive-wayne-mcgregor

Living Archive: Creating Choreography with Artificial Intelligence - Google Arts & Culture. (n.d.). Google Arts & Culture. https://artsandculture.google.com/story/living-archive-creating-choreography-with-artificial-intelligence-studio-wayne-mcgregor/1AUBpanMqZxTiQ

Natya Shastra Chapter 6. (n.d.). https://sanskritdocuments.org/doc_z_misc_major_works/natya06.html

Natya Shastra Chapter 25. (n.d.). https://sanskritdocuments.org/doc_z_misc_major_works/natya25.html

Peng, S., Ladenheim, K., Shrestha, S., & Fermüller, C. (2024). *Choreographing the digital canvas: A machine learning approach to artistic performance*. *arXiv preprint* arXiv:2404.00054.

Ploin, A., Eynon, R., Hjorth, I., & Osborne, M. A. (2022). *AI and the arts: How machine learning is changing artistic work*. Oxford Internet Institute, University of Oxford. Retrieved from https://www.oii.ox.ac.uk/wp-content/uploads/2022/03/040222-AI-and-the-Arts_FINAL.pdf Ricio, D. (2024, December 12). Inside Sphere's new Abu Dhabi venue and their patented tech. Parola Analytics. https://parolaanalytics.com/blog/las-vegas-sphere-abu-dhabi-patents/

Schwartz, B. (2022, October 24). How Google uses artificial intelligence in Google Search. Search Engine Land. https://searchengineland.com/how-google-uses-artificial-intelligence-in-google-search-379746

Talbot, C. (2013). *Creating an Artificially Intelligent Director (AID) for Theatre and Virtual Environments*. In T. Ito, C. Jonker, M. Gini, & O. Shehory (Eds.), *Proceedings of the 12th International Conference on Autonomous Agents and Multiagent Systems (AAMAS 2013)* (pp. 1457–1458). International Foundation for Autonomous Agents and Multiagent Systems.

The Economist. (2022, November 18). Why a global recession is inevitable in 2023. The Economist. https://www.economist.com/the-world-ahead/2022/11/18/why-a-global-recession-is-inevitable-in-2023

What is artificial intelligence, and how is it used? | Topics | European Parliament. (2020, April 9). Topics | European

Parliament. https://www.europarl.europa.eu/topics/en/article/20200827STO85804/what-is-artificial-intelligence-and-how-is-it-used

What is Machine Learning? Types & uses | Google Cloud. (n.d.). Google Cloud. https://cloud.google.com/learn/what-is-machine-learning

World Bank. (n.d.). South Asia Development Update, October 2024: Women, Jobs, and Growth. World Bank. Retrieved February 5, 2025, from https://openknowledge.worldbank.org/server/api/core/bitstreams/6a04abae-03fa-4335-b12e-804528a3a048/content

World Bank Group. (2025, January 17). Global economy stabilizes, but developing economies face tougher slog. World Bank. https://www.worldbank.org/en/news/press-release/2025/01/16/gep-january-2025-press-release