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Leveraging AI for the Recreation and Restoration of Ancient Indian Costumes and Accessories

Uporaba umetne inteligence za rekonstrukcijo in restavriranje staroindijskih oblačil in modnih dodatkov

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Abstract

The restoration and recreation of ancient Indian costumes and accessories are critical for preserving the nation's rich cultural and historical heritage. This review explores the transformative role of artificial intelligence (AI) in studying and interpreting primary data sources to revive traditional attire and accessories from ancient India. Primary data sources, such as textual manuscripts, sculptures, iconography and archaeological findings, offer invaluable insights into ancient fashion. Yet, their interpretation is often complex, time-consuming and prone to human error. AI, with its advanced computational capabilities, has emerged as a promising tool to analyse and reconstruct these historical artifacts with remarkable accuracy and efficiency. This paper discusses the various applications of AI, including machine learning, computer vision and natural language processing, in decoding the intricate patterns, designs and cultural elements embedded in historical data to achieve accurate results. For instance, AI-powered image recognition tools and computer vision algorithms can analyse sculptural depictions to extract information about garment textures, draping styles and accessories. Natural language processing algorithms can decode ancient textual data, such as ancient scriptures and inscriptions, to understand and extract references to fabrics, dyeing and weaving techniques, ornamentation methods and the symbolic meanings of costumes. Even archaeological findings and reports, including remnants of textiles and ornaments, can be studied using AI for material composition analysis and virtual reconstruction. These technologies not only enable the recreation of visual representations of ancient attire but also provide insights into the socio-cultural and historical contexts of the time.

This paper also highlights the challenges associated with integrating AI into this area, such as the limited availability of digitized primary data, the need for culturally sensitive algorithms and technological constraints in interpreting incomplete or degraded data. Despite these challenges, interdisciplinary approaches involving AI, history, design and archaeology hold immense potential to revolutionize the restoration of ancient Indian costumes. Despite these barriers, this study highlights the transformative potential of interdisciplinary collaboration among AI specialists, designers, historians, and archaeologists, and how technological innovation can support the accurate recreation of ancient Indian costumes and contribute meaningfully to the conservation



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and dissemination of India's cultural heritage. The findings suggest that AI-driven methodologies can not only aid in the accurate recreation of ancient attire but also ensure the sustainable conservation of India's cultural legacy for future generations.

Keywords: ancient Indian costumes, artificial intelligence, costume restoration, cultural heritage

Izvleček

Restavriranje in rekonstrukcija staroindijskih oblačil ter modnih dodatkov sta ključnega pomena za ohranjanje bogate kulturne in zgodovinske dediščine naroda. Članek obravnava vlogo umetne inteligence (UI) pri preučevanju in interpretaciji primarnih podatkovnih virov, da bi oživili tradicionalna oblačila in dodatke iz starodavne Indije. Primarni podatkovni viri, kot so rokopisi, skulpture, ikonografija in arheološke najdbe, ponujajo neprecenljiv vpogled v starodavno modo. Njihova interpretacija pa je pogosto zahtevna, dolgotrajna in podvržena človeškim napakam. UI se s svojimi naprednimi računalniškimi zmogljivostmi uveljavlja kot obetavno orodje za analizo in rekonstrukcijo zgodovinskih artefaktov z izjemno natančnostjo in učinkovitostjo. Prispevek obravnava različne uporabe UI, vključno z metodami strojnega učenja, računalniškega vida in obdelave naravnega jezika pri dekodiranju zapletenih vzorcev, oblikovnih zasnov in kulturnih elementov, ki so vključeni v zgodovinske podatke. S slednjim bi dosegli natančne rezultate. Orodja za prepoznavanje slik, podprta z UI, ter algoritmi računalniškega vida lahko analizirajo kiparske upodobitve in iz njih pridobijo informacije o tkaninah, npr. teksturi, slogu drapiranja, in uporabljenih modnih dodatkih. Algoritmi za obdelavo naravnega jezika omogočajo razčlenjevanje starodavnih besedilnih virov, kot so sveta besedila oziroma spisi in napisi, da bi prepoznali in razumeli omembe tkanin, tehnik barvanja in tkanja, načinov okraševanja ter simbolnih pomenov oblačil. Tudi arheološke najdbe in poročila, med njimi ostanki tekstilij in okraskov, je mogoče preučevati z uporabo UI za analizo materialne sestave in virtualno rekonstrukcijo. Te tehnologije pa ne omogočajo zgolj rekonstrukcije vizualnih predstav staroindijskih oblačil, temveč ponujajo tudi dragocen vpogled v družbeno-kulturni in zgodovinski kontekst obravnavanega obdobja.

Članek prav tako izpostavlja izzive, ki so povezani z vključevanjem UI na področju, npr. omejen dostop do digitaliziranih primarnih podatkov, potreba po kulturno občutljivih algoritmih ter tehnološke omejitve pri interpretaciji nepopolnih ali poškodovanih podatkovnih virov. Kljub izzivom pa predstavljajo interdisciplinarni pristopi, ki združujejo UI, zgodovino, oblikovanje in arheologijo, izjemen potencial za preoblikovanje postopkov restavriranja staroindijskih oblačil. Raziskava poudarja pomen sodelovanja med strokovnjaki za UI, oblikovalci, zgodovinarji in arheologi ter prikazuje, kako lahko tehnološke inovacije prispevajo k natančni rekonstrukciji staroindijskih oblačil in hkrati pomembno podprejo ohranjanje ter širjenje indijske kulturne dediščine. Ugotovitve kažejo, da lahko metodologije, podprte z UI, ne le omogočijo verodostojno rekonstrukcijo starodavne noše, temveč tudi zagotovijo trajnostno varovanje indijske kulturne zapuščine za prihodnje generacije.

Ključne besede: staroindijska oblačila, umetna inteligenca, restavriranje oblačil, kulturna dediščina

1 Introduction

The vibrant history of ancient India is reflected in its costumes and accessories, which symbolize the country's cultural richness and artistic excellence [1]. As Ghurye states, the symbolic and aesthetic significance of Indian costumes and ornaments reflects ancient

India's cultural richness and artistic excellence [2], while studying historic costumes and textiles helps to understand cultural evolution and artistic expression in the Indian subcontinent [3]. Through the study and exploration of primary data sources, such as old

transcripts, manuscripts, sculptures and inscriptions, we can redefine, restore and recreate the drapes of the silhouette and details of the surface development techniques of ancient costumes, along with the intricate designs of the accessories used during these periods. Additionally, this study allows us to analyse the lifestyles, values and beliefs from that time, providing a valuable source of knowledge for researchers, designers and historians. However, most of the primary data sources (manuscripts and transcripts) remain unexplored or underexplored with the vision of studying historical costumes and accessories [4]. Illuminated manuscripts are an underexplored source of information about historical costumes and accessories [5]. Some historical facts, such as sculptures and inscriptions, cannot be analysed due to degradation and destruction caused either by the passage of time or by foreign invaders [6]. At the same time, some sources cannot be decoded in terms of their chronology due to the complexity of interpreting them because of a lack of textual sources and the scarcity of inscribed works upon them [7]. Therefore, recreating and restoring the costumes and accessories of ancient times is essential for preserving and understanding the rich cultural heritage of ancient Indian textiles, costumes and accessories for the benefit of future generations. To initiate a similar effort, it is essential to study and explore available primary data sources such as ancient manuscripts, sculptures, iconography and archaeological findings. Detailed descriptions of fabrics used, ornaments designed and clothing practices are found in textual records, including Vedic scriptures, inscriptions and literary works [8]. Textual records, including Vedic scriptures, inscriptions and literary works, provide detailed descriptions of fabrics, ornaments and clothing practices [9] while the intricate details of garment structures, draping styles, designs and materials used in accessories can be derived from sculptures and iconographic art as sources of visual representations [10]. Other sources include archaeological findings, such as remnants of textiles, jewellery and dye samples, adding material evidence to these historical narratives. However, interpreting

these sets of information requires a methodical approach, precision and interdisciplinary expertise, as these sources are often fragmented and complex to decode, and their manual interpretation can be very time-consuming and prone to inaccuracies. The role of AI is vital to enable the more efficient and accurate analysis of these data. It can also play a very important role during the restoration and recreation of ancient Indian costumes and accessories based on the analysed data.

Integrating AI into the study of ancient Indian costumes and accessories holds immense potential for the generation of results. It is possible to reconstruct historical garments with high precision, offering perfect visual representations by combining advanced technologies with traditional research methods. Machine learning and computer vision technologies facilitate automated pattern recognition, image analysis and visual reconstruction. For example, AI-powered image recognition can extract fine details from sculptures and paintings, such as garment textures and accessory designs. Additionally, AI simulations can recreate virtual models of ancient attire, helping researchers visualize garments in their original context. By automating repetitive tasks and uncovering hidden patterns in data, AI enhances the accuracy and efficiency of restoration efforts. For instance, GAN-based systems have been used to recreate traditional costume designs from historical datasets, while deep learning architectures have achieved over 97% accuracy in recognizing Indian textile patterns. Moreover, text mining and NLP tools are being employed to extract meaningful insights from Sanskrit manuscripts and Pali scriptures. In the Indian context, projects such as the National Mission for Manuscripts have paved the way for large-scale digitization, creating opportunities to apply AI models to ancient texts and iconography. However, despite the growing corpus of research, very few studies have focused on using AI specifically for the systematic restoration of traditional Indian costumes and accessories through multi-modal primary data sources.

This paper aims to explore the benefits of applying AI to the systematic study of the primary data sources required to analyse the designs and styles of costumes and accessories, along with patterns and motifs used for textile surfaces, with a collaborative and interdisciplinary approach to restore and recreate them by integrating advanced tools. Its purpose is to digitally reconstruct and preserve ancient Indian attire, ensuring the creation of an authentic resource to spread the legacy of this invaluable culture. These resources can be a landmark for heritage preservation, costume designers, historians, interdisciplinary academic researchers and virtual exhibitors.

2 Background and overview

Clothing and accessories serve as an intricate communication system, enabling individuals and groups to convey their identity across various social contexts [11]. Clothing and adornment held significant importance in ancient societies, serving as markers of identity, status and cultural values. They can be regarded as valuable tools for understanding social institutions and the concepts of rank, gender and status [12]. In the Indian context, extensive literary evidence is available that describes technology, trade, social structure, cultural identity, historical context, environment and geographical constraints. These shreds of evidence serve as a valuable resource, offering significant insights while connecting its threads to the use of ancient clothing, including textiles, costumes, jewellery and other accessories used in various scenarios of a specific time and place. Traditional Indian jewellery, with a history spanning more than 5,000 years, also reflects the influence of religion, social structures and economics on personal ornamentation [13]. Historical transcripts and manuscripts can be a gold mine for studying ancient Indian culture, including costumes, jewellery and accessories [14]. Sculptures from the Paramar period, such as those found in Bhopal museums, showcase the costumes and jewellery of various goddesses, offering a glimpse into the artistic

and religious traditions of that era [15]. In the context of ancient Indian costumes and accessories, AI offers innovative approaches to decode and revive these treasures that reflect the legacy of the nation's artistic excellence and cultural depth. Integrating mathematical and computational approaches can provide novel insights into cultural elements such as costumes and revealing patterns [1]. AI can also assist in analysing and presenting museum artifacts, enhancing their visual representation for various design purposes [16]. Artificial intelligence and machine learning are considered emerging powerful tools for preserving and disseminating cultural heritage. It can aid in the virtual restoration of tangible artifacts, such as paintings and sculptures, protecting them from environmental damage and decay [17]. Existing worldwide research and methodologies that leverage AI and their applications to study primary data sources (transcripts, manuscripts, coinages, archaeological insights, sculptures, etc.) are of historical relevance, and can also be used to recreate, restore and digitalize historical costumes and accessories leveraging these tools, with a focus on the ancient Indian era.

3 Exploration of primary data sources through artificial intelligence

Current research on the use of AI to analyse primary cultural data sources, such as manuscripts, sculptures and archaeological evidence, remains limited despite AI's potential in this area [18]. AI can demonstrate its emerging potential in automated pattern recognition, visual analysis and text extraction applications specific to cultural studies, especially costumes and accessories. The integration of AI in cultural heritage research facilitates data analysis, which makes cultural content more accessible, and opens new avenues for study in archives and museums [19]. Deep learning approaches have shown promise in pattern extraction and recognition in paintings and drawings, making

visual arts more accessible to wider audiences [20]. Computer vision techniques enable automated visual inspection of heritage structures, such as temple walls, stone pillars and sculptures [21]. Additionally, large multimodal models (LMM) can identify stone deterioration patterns in sculptures [22]. These tools and techniques facilitate the exploration and validation of primary data sources.

3.1 *Textual manuscripts*

India possesses one of the world's largest collections of manuscripts, covering diverse subjects and languages [23]. Textual records, including the Vedas, Puranas, Brahmanas, epics such as the Mahabharata and Ramayana, as well as Buddhist and Jain literature, provide detailed references to the culture, social structure, costumes and accessories of ancient eras [8]. However, manually analysing these texts can be challenging due to their complexity. Recognizing the importance of preserving this cultural heritage, the Indian government has initiated digital preservation efforts. The National Mission for Manuscripts has established resource and conservation centres, developing a National Database of Manuscripts [23]. Recent research highlights the potential of AI in decoding and exploring ancient manuscripts. Machine learning, natural language processing and pattern recognition techniques are applied to interpret ancient scripts and uncover linguistic phenomena [24]. Intelligent character recognition systems, enhanced by AI, address challenges in reading cursive characters from degraded manuscripts [25]. Deep learning methods, particularly generative adversarial networks (GANs), have shown promise in restoring ancient texts, with one study reporting 98% validation accuracy [26]. Generative AI techniques can facilitate intelligent research into ancient textual manuscripts through image processing, OCR and language model-based text mining and applications [27]. Convolutional neural networks have been employed for optical character recognition of Sanskrit manuscripts, demonstrating robustness to image quality variations [28]. Deep learning models,

such as MobileNet, ResNet and InceptionV3, have been used to recognize handwritten Tamil characters in palm-leaf manuscripts [29]. An end-to-end deep learning model using MobileNet for feature extraction and a bidirectional gated recurrent unit (BiGRU) for character recognition achieved 98.48% accuracy on Tamil handwritten documents [30]. A deep neural network called Ithaca achieved 62% accuracy in text restoration and significantly improved historians' performance from 25% to 72% when used collaboratively. The system also demonstrated high accuracy in geographical attribution (71%) and precise dating within 30 years of ground-truth ranges [31]. It can assist designers in the analysis of ancient inscriptions to extract shapes and motifs engraved on them. AI also can be leveraged to assemble fragments of ancient papyrus manuscripts [32]. AI and machine learning can assist in decoding unstructured knowledge embedded in cultural artifacts, encoding data in machine-readable systems and simulating the consequences of preserving or neglecting specific human experiences [33]. Machine learning approaches are reshaping the field of ancient language study, supporting tasks such as digitization, restoration, attribution, linguistic analysis, textual criticism, translation and decipherment [34]. These advancements show that using AI to decode and summarize old manuscripts can help extract and analyse specific details about the use of costumes and accessories from ancient times.

3.2 *Sculptures and iconography*

Ancient Indian fashion can be studied through sculptures and paintings recovered from historical sites, depicting the clothing patterns, accessories and hairstyles of different social groups [8]. Sculptures can be particularly useful in developing draping skills for fashion design education, as they provide fixed mannequins with clear details for students to study and replicate [35]. In 2023, Maitra analysed pictorial evidence from Jain paintings and combined it with foreign travellers' accounts and vernacular literature to provide insights into everyday life

during this period from medieval western India to reconstruct material culture, including clothing and ornaments [36]. Sculptures and paintings from ancient temples, caves and stupas visually document ancient Indian fashion, as sites such as Sanchi, Ajanta and Khajuraho depict elaborate clothing, jewellery and hairstyles. These artifacts directly depict how costumes and accessories were worn and their socio-cultural context. Although interpreting these visual details is challenging, computer vision algorithms and AI-powered image recognition tools using contrast limited adaptive histogram equalization (CLAHE) with CNN models can provide new possibilities when analysing sculptures with a maximum accuracy of 70.66% [37]. Recent advances in deep learning tools use computer vision algorithms to detect texture, colour and structural features in ancient art and paintings, making it easier to analyse these historical resources accurately [20, 38].

Interpreting these visual details can be challenging due to erosion, damage or stylistic abstraction in the artifacts. However, the above-mentioned tools and techniques help researchers analyse sculptures and paintings, identify patterns and reconstruct missing elements. Because these tools use computer vision algorithms to examine texture, colour and structural features in ancient artifacts, when these tools and techniques are combined with expertise in costume history and costume design, they improve the interpretation of collected data and support the desired outcomes.

3.3 *Archaeological findings*

Recent excavations at sites such as Mohenjo-Daro and Harappa provide evidence of the intricate ornament styles of the Indus Valley Tradition, showcasing skilled craftsmanship in creating jewellery from precious materials, stones, shells and faience, offering valuable insights into ancient fashion. These ornaments were also replicated in more accessible materials such as steatite and terracotta [38]. Various pieces of evidence of textiles, costumes and accessories can be found and studied from impressions

on pottery and corrosion products on metal artifacts excavated from archaeological sites in South Asia [39]. Excavations at Chanhudaro reveal evidence of bead-making as a craft practiced in the Indus Valley Civilization [40]. The different types and styles of beads found in archaeological excavations across India provide insights into ancient fashion and adornment [41]. Archaeological excavations at Harappa provide evidence of specialized crafts such as shell working, ceramics and bead making from as early as 3300 BC [42]. Moreover, archaeological evidence also indicates the spread of cotton and flax textile production beyond the Harappan area in ancient India [43]. Textual data have also been analysed through text mining techniques such as natural language processing, while information extraction can be used to extract information from archaeological reports [44]. Archaeological excavations, findings and reports across India have unearthed remnants of textiles, jewellery, and tools used in garment production. Such findings complement textual and visual sources, providing a holistic understanding of ancient clothing practices.

AI and machine learning technologies can revolutionize archaeological research by enabling advanced site analysis and artifact classification [45]. AI has advanced in natural language processing (NLP) and machine learning (ML), which are great at finding patterns, making predictions and organizing information [46]. It analyses large amounts of research data stored over the years through various survey reports, helps uncover new insights, and creates opportunities to use archived data for present and future studies. The processing of images using ML has been one of the most productive areas to date for archaeologists. The forms of images vary from photographs to stylized drawings of archaeological objects. Typically, ML has been used to identify “objects” within images and describe rock art and wall paintings [47]. ML can help reconstruct and restore fragmented 2D and 3D artifacts by matching their shapes, patterns and decorations, similar to solving a jigsaw puzzle [48-50]. ML has also been employed to

reconstruct fragmented artifacts, such as ostraca, using Siamese neural networks for pairwise matching with 96% accuracy [51]. Computational techniques are being explored for the virtual reconstruction of fragmented archaeological artifacts, including textiles, to assist in the time-consuming process of matching and assembling fragments, although it has limitations because of the unique challenges of archaeological textiles [52]. These studies explain that AI, ML and computational methods have the potential to analyse text, identify patterns and explore lost parts of fragmented artifacts.

4 AI applications in the restoration and recreation of ancient Indian costumes

Generative adversarial networks (GANs) have been used in clothing design to create new patterns and styles inspired by traditional elements, as seen in Dunhuang clothing from ancient Chinese culture [53]. GANs have been employed to digitally restore eroded temple sculptures, achieving an L1 loss of 0.29 after extensive training of the model for 7, 10, 000 iterations with the objective of rebuilding images of ancient temples as they were before being damaged by several invasions and climatic changes [54]. Mathematical biology techniques have been used to analyse and classify Indian costumes across different periods, revealing characteristic features that align with traditional concepts such as *prāna* and *Yoga* [55]. The AI-driven reconstruction of ancient clothing uses a generative adversarial algorithm to extract artistic elements from ancient artifacts and apply them to costume reconstruction and digitization, combining tradition with innovation. A dataset of sculptures, coins, paintings and iconography is created to train AI models, capturing details of costumes, jewellery and accessories for historical accuracy. The generated designs are then tested against DCGAN, fashion-GAN and other GAN-based clothing design models using inception scores and

human preference to ensure they are both aesthetically pleasing and culturally accurate. AI has proven useful in art restoration, successfully reconstructing missing parts of famous paintings and decoding ancient texts. Druzhinina highlights how it also helps us to collect data from ancient temple wall art and paintings [56]. ClothGAN uses generative adversarial networks and style transfer to create new patterns and styles for historical clothing out of data collected from historical resources [57]. An enhanced variational autoencoder method for dress style migration creates more refined synthetic images of traditional Indian styles [58]. Image inpainting can be improved by using larger datasets, deeper networks and powerful GPUs for faster learning. Adjusting network layers and incorporating mathematical models can increase accuracy. Future research may focus on developing new algorithms, drawing methods and better network designs to preserve cultural and artistic details in restored images [17]. These researchers highlight that AI is transforming clothing design by blending tradition with innovation. GANs and variational autoencoders aid in reconstructing and digitizing ancient fashion, ensuring historical accuracy. Improved datasets, deep learning models and 3D visualization enhance preservation efforts. Future research will refine algorithms, strengthening AI's role in safeguarding and modernizing cultural heritage.

4.1 *Machine learning in pattern recognition*

Pattern recognition techniques have been applied to Buddhist iconography for identifying period-specific features, analysing sculptures and recognizing hand gestures in religious artifacts [59]. Convolutional neural networks (CNNs) have proven effective in identifying artistic styles, motifs, and patterns in different fields, similar to the techniques used by art historians [60]. In historical image analysis, CNNs can classify art styles and organize artworks in chronological order without needing prior knowledge of art history [61]. Pranowo used CNNs to recognize Javanese batik patterns, attaining 90.14%

accuracy [62], while Kuntitan applied CNNs to classify motifs on Sukhothai ceramics, achieving 86.54% accuracy with a fine-tuned VGG16 model [63]. Similarly, CNNs have demonstrated exceptional accuracy in recognizing Indian textile patterns, with one study reaching 97.15% accuracy by combining CNN features with curvelet transforms [64]. The integration of ML algorithms in fashion design classification facilitates automated analysis and categorization based on different attributes, transforming the study of historical fashion. However, challenges such as data variability, interpretability and ethical concerns still exist [65]. Although there are some concerns, the researchers highlight the effectiveness of ML in studying historical fashion by automating pattern detection and classification. CNNs can recognize detailed surface patterns and silhouettes in sculptures and paintings. ML algorithms classify traditional Indian motifs such as paisleys, florals and geometric shapes, aiding in the accurate reconstruction of ancient garment designs.

4.2 *Natural language processing (NLP) for text analysis*

Recent research demonstrates the significant potential of NLP, making it an essential tool for analysing ancient Indian texts. By converting manuscripts into digital formats, NLP models can extract relevant information about clothing and accessories, such as descriptions of fabrics, dyeing techniques and weaving patterns. A novel system combining machine learning, image processing and NLP was proposed by [66] to convert Pali characters into understandable formats and decode the Pali Prakrit language, improving character recognition accuracy, and contributing to the preservation and study of this cultural heritage. [67] developed a question-answering model using BERT embeddings and gated recurrent unit (GRU) layers, achieving high accuracy rates on ancient Hindu scriptures, specifically the Atharv Ved, demonstrating a high accuracy rate of 94%. [68] introduced Vedalytics (Ved Analytics), an approach to retrieve the rules and concepts from

various ancient Indian scriptures, demonstrating improved specificity compared to generic language models. NLP strategies such as topic modelling and sentiment analysis have also been used to compare religious scriptures, revealing shared themes and differing perspectives across texts from Hinduism, Islam and Christianity [69]. Text classification and optical character recognition (OCR) are important areas of natural language processing for Indian languages, particularly Sanskrit. For the text classification of Indian language content, supervised learning algorithms such as Naive Bayes, Support Vector Machine, Artificial Neural Network and N-gram have shown good performance [70]. These studies highlight the effectiveness of NLP and AI in decoding, preserving and enhancing accessibility to ancient Indian texts, contributing to the understanding and conservation of cultural heritage.

4.3 *Computer vision for image analysis*

In the early days of advanced technology involvement, [71] used petrography and electron microprobe analysis to study the materials of Indian stone sculptures. This method examined artifacts from various regions and periods, such as Gandharan schist and Hoysala sculptures. Though limited, the study showed the potential for further research in identifying Indian stone artifacts. These studies contribute to the growing use of computational and analytical methods in this field. In a different approach, [72] developed a deep learning model to automatically recognize various features of Indian monuments from images, such as architectural style, time period and type. Their model was tested on a dataset of over 6,000 images from 117 monuments and achieved more than 80% accuracy. Similarly, [73] employed DCNN for monument classification, attaining 92.7% accuracy on a dataset of 100 monuments.

Recent advancements in computer vision have greatly contributed to studying traditional garments and iconography. Researchers have trained the advanced YOLOv8 model to identify traditional

costumes from different countries. For Indian saris, the model achieved an impressive 99% mean average precision [74]. In archaeology, machine learning and computer vision are helping to discover new details about Copper Age Iberian oculated idols, revealing artistic variations and regional differences that were previously unnoticed [75]. Deep feature fusion and content-based image retrieval systems such as InceptionV3 and InceptionResNetV2 models are being developed to assist designers in creating new motifs inspired by traditional patterns [76]. These tools have the potential to analyse sculptural and pictorial representations to identify draping styles, garment structures and jewellery designs. AI-powered systems can be successfully deployed to recreate digital models of ancient Indian attire by extracting details from temple sculptures.

4.4 3D modelling and virtual reconstruction

Virtual reconstruction is another significant application of AI in this field. AI technologies facilitate the creation of 3D models using textual descriptions, photographs, paintings and archaeological data, providing immersive insights into historical artifacts and costumes. [77,78]. AI has made remarkable progress in generating images from text descriptions and reference images. State-of-the-art AI tools, such as DALL-E 2, can produce high-quality images from text prompts and use a reference image to guide the process [79]. Even for 2D restoration, a framework combining neural style transfer, U-Net and Partial Convolution networks have been developed to repair damaged regions in ancient Indian murals [80]. This suggests that when AI image generation technology matures in the next few years, it could become a valuable tool for creating the virtual reconstructions of artifacts in the future. AI technologies enable the virtual reconstruction of ancient costumes and accessories, offering immersive insights into cultural heritage. These technologies support the cataloguing of cultural collections, the restoration of artworks and the preservation of intangible heritage [81]. Despite its limitations, AI-driven integration systems

have the transformative potential to digitally recreate and restore ancient costumes, offering a unique perspective to explore and share the rich history of costumes with future generations [82]. Recent research highlights the expanding role of AI in virtual reconstruction and restoration by integrating data from textual, visual and archaeological sources. By leveraging AI, researchers can generate 3D models of ancient costumes and accessories, while emphasizing ethical considerations such as data privacy, cultural authenticity and community involvement. These 3D models offer immersive insights into how garments were worn and their cultural significance, enhancing museums and educational platforms to bring ancient Indian fashion to life.

5 Challenges in AI-based restoration efforts

Even though AI has potential, using it to recreate and restore ancient Indian costumes, textiles and accessories has many challenges. The cultural dependencies embedded in AI technologies, predominantly developed in a handful of countries, can lead to incongruencies when applied globally [83]. The development of a culturally sensitive AI model, trained in regional aspects, will be required. Generic algorithms may fail to capture the nuances of regional variations and symbolic meanings inherent in Indian costume analysis. It is important to design AI systems that include the historical, cultural and social backgrounds of ancient India for accurate restoration.

Furthermore, general puzzle-solving algorithms, especially those based on deep learning, have shown promising performance on artificially fragmented natural images. However, they face some challenges when used for studying archaeological textiles [84]. When dealing with highly incomplete pieces, a hybrid human-computer approach is often necessary. This method combines expert knowledge with computational solutions to achieve credible

restorations, as demonstrated in the reconstruction of Roman sculptures [85]. It shows that interpreting incomplete or degraded data poses technological constraints. Artifacts that are partially damaged or eroded require advanced algorithms capable of reconstructing missing elements without distorting historical accuracy.

5.1 *Limitations of AI in Interpreting cultural nuance*

The application of AI in historical costume restoration is accompanied by notable limitations, particularly in addressing cultural nuance and contextual integrity. AI-generated reconstructions, when reliant solely on data-driven algorithms, are susceptible to inaccuracies that may distort the original intent of traditional attire. These models often fail to account for the socio-cultural, religious or ceremonial significance embedded in garments, especially when training data lacks representational diversity or is devoid of ethnographic context [83]. These limitations lead to the oversimplified outcome where complex draping techniques, symbolic textile patterns and region-specific stylistic variations are often distilled into visually coherent but historically inaccurate representations, even if they may be aesthetically convincing. This result will interpret the cultural identity.

5.2 *Data gaps in training AI models*

One of the most significant obstacles in AI-assisted historical costume restoration is the availability and quality of primary data. Many traditional sources from ancient manuscripts, sculptures, paintings and textile fragments are either degraded, inaccessible or not digitally accessible. Additionally, cultural and linguistic diversity in the same era of ancient India makes it harder to understand correctly in the case of the detailed information related to costume analysis. Inadequate data volume or resolution limits the robustness of training datasets, which directly impacts the accuracy and reliability of AI outputs. Moreover, historical records often lack standardized

documentation, leading to inconsistencies in meta-data, terminology and visual representation across sources. These data gaps introduce biases and errors in model training, where the algorithm overfits to dominant styles or well-preserved artifacts, while underrepresenting regional or marginalized traditions. As a result, reconstructions may reflect only a narrow slice of cultural history, distorting the broader narrative. In the case of rare fragmented datasets, AI may generate an outcome based on statistical inference rather than historical accuracy, which can compromise the authenticity of the restoration [86].

6 Conclusion

The enduring value of India's ancient costumes and textiles, with the intricate techniques of weaving, dyeing, printing and embroidery, reflects the craftsmanship of earlier generations and serves as a testament to the diversity of India's textile heritage [87]. These studies find that collaborative efforts between AI experts, historians and designers are crucial to addressing these challenges effectively when making efforts to recreate and restore historical costumes and accessories with precision. China's digitization of Dunhuang textiles has leveraged GANs and deep learning to reconstruct traditional garments with high aesthetic fidelity [54], while European efforts in Byzantine mosaic restoration employ multimodal AI systems that integrate textual, visual and archaeological data for contextual accuracy. Even initiatives such as the restoration of Shakti sculptures from the Paramara period [15] and Indus Valley ornament styles [40] highlight how computer vision and deep learning tools are being applied to study the intricate designs and motifs found in archaeological and sculptural artifacts. For instance, deep learning models such as CLAHE-enhanced CNNs have been used to classify and extract features from Indian sculptures with over 70% accuracy [39], aiding in the interpretation of garment structure and jewellery design.

Additionally, AI models have been deployed to decode palm-leaf manuscripts and Sanskrit inscrip-

tions [30, 32] helping reconstruct cultural knowledge surrounding ancient clothing practices, fabric usage and textile production methods. These efforts reflect an emerging trend in India that integrates natural language processing, computer vision and machine learning to recover fragmented historical narratives through primary sources. These studies contrasted with traditional restoration techniques such as the manual decoding of scripts, artisan consultation, textile analysis, manual sketching and artisan-led reconstructions, and offer deeper cultural understanding and material sensitivity but are often time-consuming and resource-intensive. Thus, by integrating AI-driven methodologies with traditional research practices, it is possible to achieve more accurate and comprehensive results. Combining AI's computational power with traditional expertise, a hybrid model emerges as the most viable approach. Such integration ensures the technical precision, cultural authenticity and ethical responsibility necessary in preserving intangible heritage.

Future research should focus on expanding the digitization of primary data sources and developing region-specific AI models. Collaborative projects between cultural heritage institutions, universities and technology companies can accelerate advancements in this field. Additionally, incorporating augmented reality (AR) and virtual reality (VR) technologies can enhance the visualization and accessibility of ancient Indian fashion for educational and cultural purposes. This study emphasizes the importance of balancing technological innovation with ethical considerations, advocating for ongoing dialogue among stakeholders to ensure AI in fashion evolves responsibly, inclusively and ethically, ultimately fostering a harmonious coexistence between technology and human creativity.

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