

Real Time Museum Monitoring of Basohli Paintings Using Hybrid AI Techniques

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Abstract

Basohli painting, one of the first and most influential schools of Pahari miniature painting, in museum, scholarly and community contexts, is important culturally. Its fields of saturated colour, its use of paper supports, its red borders and its raised white ornamentation and occasional metallic or beetle wings embellishment make these works visually distinctive and yet materially vulnerable. In museum practice, preservation still depends largely on periodic manual inspection, which is important but tends to be too rare to detect the degradation of an artifact in its early stages e.g., pigment instability, foxing, edge abrasion, environment induced deformation. This paper proposes a hybrid artificial intelligence architecture for the real time visual monitoring of Basohli paintings in the collections in Indian museums. The framework comprises high resolution RGB imaging, optional multispectral or hyperspectral amount evaluation, environmental sensors amount stream, segmenting a defect of then an abnormal affect, self supervised training of it, explanation say scoring and explanation prepare dashboard for conserve a self of it. It is designed as a non contact, low light, modular and a curator centred systems which can be adapted to institutions with different levels of technical infrastructure functioning from small museums with RGB imaging, microclimate sensing, to spectral imaging and including built in conservation databases systems to more advanced collections. The five distinguishing contributions that the article provides are a Basohli specific deterioration taxonomy; a modular multi mode monitoring pipeline a data acquisition and annotation protocol, as an application at the museums; a model validation blueprint with an anthropocentric system, taking into consideration both the model performance and the waste burden of false alerts; and a layer of governance that corresponds to museum ethics while being trustful AI. Instead of delivering a pre completed many site trial, the paper offers the foundation for a solid methodological and deployment policy for the eventual validation of pilot in museums in India.

Keywords: Basohli painting, preventive conservation, cultural heritage AI, museum monitoring

1. INTRODUCTION

Basohli painting is generally recognized as one of the earliest and most characteristic schools of Pahari miniature painting, which flourished in the last quarter of the seventeenth and eighteenth centuries in the hill states belonging to present day Jammu and the adjoining areas. Art historical scholarship has regularly identified the school by its inlaid fields of red, ochre, green and brown, profile faces with stylized large expressive eyes, oblong formats; and striking linear vitality. In some surviving examples these visual characteristics are also enhanced by technically complex decor, such as raised white ornamentation and

jewel like inlays of beetle wings, which adds to the luminosity whilst at the same time adding a layer of material fragility and difficulty of documentation.

Today, works of Basohli art life both as scattered museums of global value and as extant and continued signs of regional cultural identity. Important Indian holdings are preserved in such institutions as the National Museum, New Delhi however, the Dogra Art Museum, Jammu, especially, is associated with Pahari miniature collections. At the same time, both spellings, "Basohli" and "Basholi", are still used in contemporary governmental and craft promotion discourse in relation to the artistic history of the region, and of course, when referring to the GI-recognized craft context of Kathua district. For terminological consistency purposes, the art historical form Basohli has been used in this study in the main text, and Basholi used in this study's title and keywords, in order to reflect current use in India.

From a conservation standpoint Basohli paintings are especially challenging to conserve because they present a combination of the weaknesses of works on paper with high susceptibility of painted and decorative surfaces. Preventive conservation recommendations for paper based collections focus on minimizing light exposure, UV filtration and stable temperature and relative humidity conditions, while the conservation literature on paintings thus also focuses on the hazards involved in thermal stress, environmental fluctuation, pollutants, deformation, lifting and surface pollution. In the practical museum context, however, these potential risks are not limited only to storage environments, but rather occur throughout the entire cycle of storage, exhibition, transport, handling and loan, so that overall monitoring is a key part of long term preserving.

Despite these requirements, routine preservation is still dependent on periodic manual inspection supported by condition reports, photographic records and environmental logs in many museums. Such practices are necessary, of course, but are in addition spatiotemporally sparse and operationally uneven. Minor but accumulative changes, such as structural changes including instability of pigment, onset of foxing, abrasion of edges, localized deformation, or early surface disturbance, may begin to appear between intervals of inspection and be without documentation until they occur at higher levels. These limitations take on special significance in applications in which the range to specialist capacity for conservation, imaging infrastructure and standardised documentation workflow are unevenly distributed from one institution to another.

In parallel, heritage science has experienced a tremendous increase in methods with the use of artificial intelligence, computers based on computer vision, spectroscopy imaging, and computer based monitoring system inspired by the concept of the digital twin. Recent reviews and case studies provide evidence of the growing use of machine learning based approaches for cultural object damage detection, pigment types classification, restoration aid, risk prediction, hyperspectral analysis and real time monitoring of cultural objects and built heritage and also increasing focus on models explainability and uncertainty estimation and trustworthy AI for applications in cultural heritage. However, the use of these methods for miniature paintings on paper is still very limited, and Indian tradition such as Basohli is far from well represented in the literature. This is an important gap, which is because the context of the Basohli painting in terms of material and stylistic aspects are different in important ways from the grander form of canvas paintings, murals or the stone heritage objects that dominate existing AI-driven conservation studies.

This paper addresses the gap in the literature by proposing a hybrid artificial intelligence (AI) framework for a real time visual monitoring system for and preventive conservation of Basohli paintings in Indian museum collections. The proposed framework comprises high resolution RGB imaging, optional multispectral or hyperspectral acquisition, environmental sensor stream, defect segmentation, self

supervised anomaly detection, explainable risk score as well as curator facing digital dashboard. It is conceived as a non contact, low light, modular and institution scaling system which may be adapted to different levels of technical readiness, ranging from museums with standard imaging and microclimate sensing to those with sophisticated capabilities of spectral and the database integrated ones.

The paper makes five main contributions. First, it converts the material/stylistic singularities of Basohli painting into a taxonomy of deterioration of a monitoring nature. Second, it proposes a multimodal architecture for the fusion of the visual and environment evidence in the workflows of preventative conservation. Third it argues for an outline of a data acquisition, annotation, governance and model validation protocol for a museum. Fourth it proposes a deployable roadmap that will enable scalability to the infrastructural diversity of Indian Museums. Fifth it makes an explainability, uncertainty handling and ethical oversight an integral part of the framework, and not an add on.

Rather than reporting on a completed multi-site trial, this article is placed in the category of a methodology and deployment study. Its aim is to provide a foundation of strict conceptual and operational framework towards implementation and validation of pilots in Indian museum collections; in addition, it forms part of the wider discussion on the future role of hybridizing artificial intelligence for preventive conservation in culturally specific and materially sensitive heritage fields.

2. Culture and Material Context of Basohli Paintings

A sound scheme for monitoring Basohli paintings needs to be based on the cultural and material specificity of the class of object. Basohli works are not just small art images that can be easily subjected to generic forms of visual analysis, but are instead materially layered heritage objects in which stylistic grammar is inextricably bound with conservation requirements. This is described in museum documentation and art historical study as being paintings on paper and painted in opaque colour or water based media, often enhanced by gold, silver, raised white detailing and other features of the relief technique. There are the Rasamanjari folios, the scenes of Bhagavata Purana and Gita Govinda, portraits and devotional compositions in the corpus. In such works the borders are part of the visual and symbolic structure of a work and not merely marginal ornament. As a result, edge abrasion as well as perimeter losses and frame shadow effects, may be inappropriately significant both for interpretation and for condition assessment.

These are characteristics which provide a special set of problems in monitoring. Because of their small format, real deterioration which cannot be seen in the ordinary collection photography can be at sub millimetre level. The saturae or palpable reds, yellows and earth tones typical of the school are also prone to the inconsistency and drift of colour management and illumination, making the difference between actual material change and the variability of acquisition even more difficult. Reflective features, such as metallic decorations, glazing and inlays regular repetition of visual features such as beetle wings might be responsible for glare and specular artefacts that can disrupt image interpretation and automatic analysis. At the same time, the paper support may react to changes in relative humidity by cockling, warping or local deformation even before the obvious visible disruption occurs in the painted layer itself. Monitoring Basohli paintings thus needs an integrated solution using a high resolution imaging in combination with spatial registration, colour calibration, glare control and environment sensing.

In this context monitoring has a essentially preventive purpose. The aim is to be able to detect weak signals of change as early as possible to enable minimally invasive action with, for example, environmental correction, display condition review or targeted examination by a conservator as opposed to waiting for damage to proceed to a curative stage. Accordingly, Table 1 constitutes a synthesis of the main

deterioration risks that apply to paintings on Basohli, as well as corresponding measurable indicators that can be used in favors of a systematic surveillance in museum settings.

Table 1. Basohli specific deterioration risks and measurable indicators

Risk factor	Typical symptom	AI / sensor signal	Preventive response
Cumulative light dose	Fading, border dulling, colour drift	Lux hours trend, Delta E against baseline	Reduce exposure time; review case lighting
RH / temperature fluctuation	Cockling, planar distortion, lifting risk	Variance and rate of change features	Stabilize enclosure and HVAC settings
Dust / pollutants	Haze, particulate deposit, staining	Texture anomaly + PM / VOC peaks	Case cleaning and filtration review
Foxing / biological activity	Brown specks, diffuse growth, staining	Spot detection + humidity anomaly	Targeted inspection and isolating response
Handling / framing stress	Edge tears, border abrasion, corner wear	Boundary-region change map	Mounting review; handling restriction
Material layer instability	Crack, flake, incipient paint loss	Segmentation heatmap + temporal alert	Conservator examination before further display

3. Related Work and Research Gap

In recent years, machine learning has become more than an isolated methodological experiment that has now been recognized as a relatively young but still well defined field of painting conservation and heritage science. Recent reviews include several recurring application domains including enhancement of scientific imagery, pigment analysis, damage detection, virtual restoration and deterioration prediction and persistences such as lack of annotated data, lack of longitudinal data and uneven integration into the conservation workflow. Harth's review of machine learning for pigment studies goes on to indicate that computational methods are gaining increasing importance not only for the automated classification of data but also for the structuring and interpretation of complex analytical knowledge in heritage studies. Within the context of the Indian setting, Garg and colleagues have shown the potential value of deep learning for the digital preservation and retrieval of Indian art heritage collections albeit they were concerned with access and classification, and not with material condition assessment or preventive monitoring.

The most pertinent studies with potential for implications for conservation monitoring have mostly come from mural and painted-heritage contexts. Zhan and co-authors have proposed a technique for real time computer vision for damage detection of cave paintings in Yungang. Yu et al. present an automated framework for labelling paint loss deterioration with hyperspectral classification and segmentation, while Gao and colleagues prove the usefulness of hyperspectral imaging for the non-invasive digital protection

of mural surfaces by surface analysis. Liu and co-workers also report the use of hyperspectral imaging assisted by machine learning for the identification of pigments in Thangka paintings. Collectively, these studies form the basis for establishing the conclusions that non-invasive heritage diagnostics can be supported by high resolution imaging data, spectral data and an AI based analysis. However, the object classes they address differ considerably from paper based Indian miniature paintings. Basohli works are not only smaller in format, but they are also frequently viewed or stored under glazing, are exceptionally light sensitive, and are materially dependent on paper supports and frail surface embellishments. These differences limit the direct transferability of standards monitoring frames existing of mural and panel oriented.

A second strand of literature is of interest, related to environmental intelligence and systems/whole ecosystem integration. Wang and colleagues bring the thoughts of digital twins into the domain of preventive conservation for movable wooden artefacts, showing the value of connecting environmental data, risk assessment and decision making for management in near real time. Krasevec and co-authors lament the lack of seasonal monitoring of indoor air pollutants in the museum environment. At the same time, Paolanti, Frontoni and Pierdicca suggest that if AI is to be used in cultural heritage, it is important that it is trustworthy, interpretable, and bias aware in order to enable responsible professional practice. When read together with the ICOM Code of Ethics and the framework by the UN's educational agency, the United Nations Educational, Scientific, Cultural and Sports Organization, on the ethics of artificial intelligence, this literature would seem to imply that museum artificial intelligence systems should be auditable, accountable, and explicitly subordinated to human expertise and institutional responsibility.

Taken together, the literature confirms that artificial intelligence is no longer missing heritage conservation. The more important problem is the lack of an integrated framework for finding solutions to specific needs of the Basohli painting and associated Indian miniature traditions. Existing research generally focuses on single tasks such as pigment identification, damage segmentation, retrieval or environmental analysis without integrating within one preventive conservation architecture all of the following: object sensitive imaging, optional spectral diagnostics, environmental sensing, explainable inference and museum workflow governance. To the best of current knowledge there is no published study as yet that has offered such a framework specifically for Basohli paintings or drawings closely related to them in collections of India Peggy capita of Indian miniature painting from the Archives of Oriental Art and Art of the Islamic World in Paris. The present paper is therefore located as a methodological blueprint that is supposed to fill this gap with a hybrid, scalable and curator centred framework for a real-time visual monitoring and preventive conservation.

4. Proposed Hybrid AI Framework

This study proposes a hybrid artificial intelligence framework for the preventive monitoring of Basohli miniature paintings which is conceivably designed as a conservation based decision support architecture and not the computational pipeline. The framework is organized according to six interlinked design principles that are non contact acquisition, operational safety in low light, colour managed reproducibility, multimodal data fusion, explainable inference and human in the loop decision making. Within the current context, the word hybrid should not be considered when someone only thinks of a specific typology of model, but they are the intentional integration of supervised vision models, self supervised anomaly detection, rule-informed environmental evaluation, spectral interpretation and expert conservator review in a single operational ecosystem. Such an approach would be especially suitable for Basohli miniatures,

which owing to their material delicacy and fine pictorial detail, not to mention sensitivity to environmental fluctuation, through a monitoring paradigm that was able to balance analytical rigor with professional interpretive oversight.

4.1 Acquisition Layer

The framework starts with the creation of a baseline reference record for each object which is preferably produced soon after conservation treatment, photography of the object upon accession, or a reference imaging session for the object at the direction of a curator. This high-resolution, three dimensional baseline record is preferably in the form of an RGB image with a very narrow image acquisition of interior. The camera under carefully controlled illumination conditions, chromatically calibrated to the colour of a collection target, a scale reference and relevant meta data from collection. For those objects that are determined to be high value, structurally unstable or historically susceptible to deterioration, periodic raking light imaging may be implemented to help increase visibility of variations in surface topography and incipient rates of deformation on the object's surface. Multispectral or hyperspectral imaging, while necessarily more selective due to the institutional and logistical constraints, may be attempted at longer intervals or put in action at the behest of the alert from algorithms or the curiosity of curators. Alongside image capturing, polynomial testing parameters should include recording of temperature, relative humidity, cumulative radiation exposure in light, ultraviolet load and/or pollutant surrogates, such as at the volatile organic compounds or particulate matter level. In this respect, the acquisition layer is set up with the aim of documenting not only appearance, but creating an evidentiary baseline against which there could later be interpreted visual change in relation to environmental history.

4.2 Pre processing and Registration

Every newly acquired image undergoes correction of lens distortion, colour normalization regarding a calibrated workflow as well as spatial registration to a baseline reference image. Registration is especially important in the case of miniature paintings, as even small discrepancies in the position of the cameras can lead to some artefactual differences which simulate real structural change. A Basohli specific masking protocol has the advantage of preserving the painted border and eliminates mounting artefacts as well as specular reflections of painted images arising from glazing or metallic ornamentation. This preparatory stage produces harmonized image tiles and differential maps as feeding inputs for all the further processing modules.

4.3 Hybrid AI Core

The hybrid AI core is made up of interior four modules that come with their complementary features. The first module is a supervised defect segmentation component which is trained given expert annotations of cracks, flaking, paint loss, foxing, mould like spotting, abrasion and border damage. The second part is a self supervised anomaly detector that learns the distribution of the normative visual of each object or object class, thus enabling to identify never before seen deviations without the need for labels to each object class. The third component is a spectral consistency component, which is used in the presence of multispectral or hyperspectral data to identify anomalies in the concentrations of pigments, moisture associated changes, and mismatches of restorations which are less noticeable in the RGB imagery alone. This is complemented by the fourth component, an environmental risk engine, whereby histories of sensors are used to develop preventive conservation exposure variables such as cumulative lux hours, relative humidity instability and an overload of pollutants.

These outputs are fused into a condition risk score for each object at time t , expressed as

$$R_t = \alpha V_t + \beta A_t + \gamma E_t + \delta \Delta_t$$

where V_t is supervised visual-damage severity, A_t is the anomaly score, E_t is environmental exposure risk, and Δ_t is time progression between successive image acquisitions. At first they are determined by domain experts as parameters for the weighting; the optimisation is brought about through museum-specific calibration procedures. The score is meant to not automate intervention, but instead emphasize expert review process, standardize protocols for use in the triage process and highlight trends that can be obtuse across visual data and environmental records.

4.4 Explainability and Uncertainty

In order to balance such risks posed by false positives, the framework has a dedicated layer of explainability. Each alert generated must be accompanied by a localization map or area overlay, a quantitative confidence estimation, and an autogenous mode of abstention, which comes into play anything lower than a predefined confidence threshold, or image quality is affected due to glare issues, unfocused build-up, or luminosity level. In a professional sense, the system is needed to provide the rationale behind the concern and indicate periods of uncertainty. This requirement is in tune with modern expectations of trustworthy artificial intelligence in the cultural heritage sector and in accordance with the ethics within museums that are focused on transparency and professional accountability.

4.5 Decision support and Digital twin

The ultimate artefact is a complex dashboard or digital twin style object interface showing the baseline image, the contemporary image, change maps, risk trajectories, traces from the environment and features included in the annotations by conservators. Rather, instead of replacing the condition report of yore, the dashboard is intended as a dynamic extension of it. Consequently, the museum is able to move away from sporadic documentation toward a continuous regime of monitoring under the control of a curator.

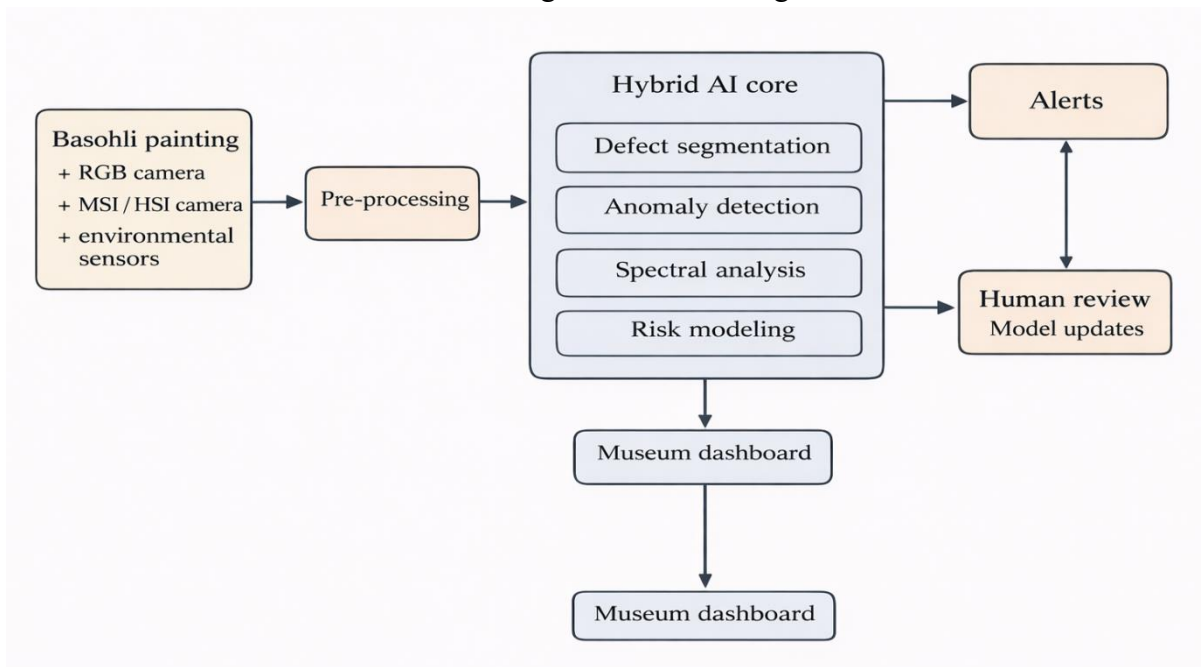


Figure 1. Proposed Hybrid AI Architecture for Basohli Painting Monitoring

Figure 1. Proposed Multimodal Architecture to connect calibrated imaging & Environmental sensing, with Hybrid AI based inference and Conservator guided Decision Support.

5. Dataset, Annotating and Validating

A powerful dataset for monitoring Basohli painting should be organized on the level of the object, instead of the level of the images. Each record should combine an integration of metadata collection of the accession's metadata information, characteristics of the support and medium used, conservation history, framing and glazing information, place of display or storage, baseline reference imagery, subsequent monitoring capture, and starting point captured environmental measurements with a temporal coupling. Given that Basohli collections will typically be spread across institutions with widely differing imaging infrastructure, the presented framework should be compatible with federated multi-institutional contribution of data and also when applied locally and de-centrally.

Annotation needs to be conservative, precise and scalable and label definitions must be based on conservation practice. A minimum, annotations should discriminate between, for example, crack or fissure, and paint lifting or incipient paint flaking, paint loss, foxing or brown spotting, mould like growth, dust or particulate deposition, edge tear or box border abrasion, glazing reflection artifact and previous restoration zone. As in heritage datasets the same type of pixel-wise annotation can be a prohibitively expensive undertaking, a hybrid approach to annotation is recommended, combining bounding boxes, sparse polygons, and object level risk tags. In addition, active learning workflows must be designed to help experts focus their attention on uncertain, ambiguous, or risky areas, instead of wasting an excessive amount of effort on routine negative samples.

Validation must be designed to represent how museums operate and decisions are made and not used to represent conventional machine learning benchmarks. Standard technical measures like mean average precision (MAP), Dice Coefficient, intersection over union (IOU), area under the receiver operating characteristic curve (AUROC), F1 Score, etc. are still required for evaluating algorithms but such measures are not sufficient for deployments in the real world. From a museum perspective a list of operationally meaningful indicia comprises of the false-alert burden per object month, average time from initiation of change to trigger of the alert, time of stability of colour measurements under routine recapture conditions and time consumed to verify or dismiss an alert by a conservator. Accordingly, the validation framework should be combined of technical, operational and human factors measures as summarised in Table 2.

To reduce data leakages and false performance estimations, the splits of the training, validation and test data should be done on the object level and, wherever possible, at the level of the institutions. A second temporal hold out set is also suggested so the models are tested on future captures and not random shuffled images of the same acquisition session. Cross institution validation is especially important as the display cases, local illumination conditions, camera systems and glazing materials are all likely to be quite different at different Indian museums. Without some of the aforementioned controls, the model could potentially fit not on truly generic signatures of deterioration, but on the imaging pipeline of a single institution.

Table 2. Suggested validation framework for a Basohli monitoring deployment

Module	Example input / label	Primary metrics	Operational meaning
Defect segmentation	Crack, flake, foxing, abrasion masks	Dice, IOU, precision, recall	How accurately visible damage is localized

Anomaly detection	Baseline vs future unlabelled captures	AUROC, F1, false alerts / object month	Sensitivity to unseen micro change without over alerting
Colour drift tracking	Calibrated RGB patches / spectral bands	Delta E00, trend slope	Distinguishes real chromatic drift from capture noise
Sensor risk engine	RH, T, lux, UV, VOC / PM streams	Alert precision, time-to alert	Whether environmental anomalies predict actionable risk
System usability	Conservator review session logs	Verification time, trust score, override rate	Whether the system is acceptable in professional workflow

Recommendation also report the algorithmic accuracy and back working upon the burden of the workflow. A museum safe model can be chosen instead of a slightly more accurate model as long as it reduces false alarms and unnecessary handling significantly.

6. Deployment Roadmap for Indian Museums

The proposed framework is organized in a way that allows for the scalable implementation of its framework in three tiers of deployment thus catering to the heterogeneous operational realities of Indian museums. Tier 1 represents cost rational entry level configuration appropriate to institutions that are restricted to controlled RGB imaging, together with basic environmental sensing. Tier 2 goes to the next level of development by the inclusion of raking light imaging, edge based computation, and more systematic metadata integration. Tier 3 is the highest level of configuration, and represents an intervention that includes periodic multispectral or hyperspectral examination, pollutant sensing and interoperability with conservation databases and collection management systems. Such a tiered architecture makes sense especially in the Indian museum world, where we do have great variability in staffing, equipment budgets, climate control infrastructure and degree of digital maturity.

Viewed from an operational point of view, each object is introduced into this system in a curator authorized baseline documentation session. Thereafter, objects on display might be monitored at specific intervals, for example, daily, weekly or in response to specific events, depending on the risk category and institutional logistics. Objects in storage may be evaluated less often, but are still analytically connected to current environmental trends. Alert generation is intended to facilitate a staged decision process: initial evaluation is done at the dashboard level and only the ones that are backed up by enough evidence will get pushed tools to be evaluated up close. This workflow reduces unnecessary handling and increases the amount of accountability, consistency and traceability in the decision making process of conservation.

A further strength of the framework is that it enables the standardization of documentation between changing object states and institutional contexts. A unified record of objects can travel with an artwork during storage, exhibition, transport, and return incorporating image chronology, environmental history and treatment documentation in a continuous digital profile. This continuity is particularly important for

fragile works on paper where deterioration can be subtle, cumulative and only readable to be seen over long periods of time. In this regard, the framework goes further in the pretend digital preservation agenda that is already emerging within the field of Indian heritage AI research, and reorienting it in the direction of a conservation specific and decision support oriented application.

7. Governance, Ethics and Trust Worthiness

Any AI enabled system for informing prioritization in conservation systems at museums will need to be embedded in a clear and articulated ethical and governance framework. First, such a system should serve as a decision support tool and not as a decision substitute mechanism. While a model may help to identify and rank risks, it cannot properly permit conservation treatment instead of qualified professionals. Second, all of the alerts need to be fully auditable. Museums should be able to view the source image, the region of interest that was flagged, the environment of the situation that brings about the flagged condition, and most importantly, the model version that was used to generate the alert. Third, institutions need to formulate explicit policies related to image permissions, archive storage, and sharing of data between institutions, especially with heritage records of cultural or legal sensitivity. The level of governance proposed in this framework is informed by three normative foundations that are complementary to one another: trustworthy AI principles arising from recent heritage science scholarship, the ICOM Code of ethics for museums, and the ethical framework of artificial intelligence proposed by the United Nations Educational, Scientific and Cultural Organization. Operationally this means maintaining meaningful human control, capturing the model uncertainty, testing for bias under numerous variable imaging conditions, refraining from opaque forms of automation, and upholding professional accountability counting professional accountability clearly rather than being an obfuscating nerve embedded within software systems. It further requires careful calibration of the sensitivity of models so that outputs from monitoring do not lead to alarm fatigue or leads to Margaret handling of fragile paintings unnecessarily.

8. Discussion and Future Research

The key contribution of the proposed framework is the fact that it is strongly linked to the practical aspects of conservation and the architectural demands of AI enabled monitoring. Instead of conceptualizing monitoring as a static process of classification according to isolated images, the framework addresses monitoring as a longitudinal and context dependent process where visual appearance, environmental conditions, model uncertainty and professional judgment are intrinsically connected. This view is likely to be of more practical value for museum conservation compared to models based on imagery resulting in high predictive accuracy and yet detached from working and material context.

At the same time, there are a number of challenges that need to be recognised. Datasets for Basohli paintings are likely to have a small size, the process of annotation will be a resource for itself, and class distribution will likely be strongly imbalanced. In the initial phases of the deployment, optical variability caused by glazing, mounting circumstances, or changes in the setting of the camera might add significantly to model error. Although spectral imaging has some great analytic benefits, its routine application may not be feasible in institutions with limited technical capability. Furthermore, Basohli objects exhibit extra elements that can be considered forms of visual complexity, potentially confounding automated process systems: reflective embellishments, textured borders, aged paper tonality, traces of earlier repair and could all be mistaken as signs of deterioration without any contextual grounding. These limitations reveal the

importance of using object specific baselines, domain adaptation techniques and abstention wise system design.

Future research therefore should move in four related directions: First of all, pilot implementations of the framework should be tested on a limited corpus of paintings spread across one or more display galleries and an average storage environment. Second, having the development of spectral reference libraries which are specific to Basohli material composition would aid in the interpretability of pigment change and surface condition analysis. Third, these federated or other privacy preserving learning methods across Indian museums might open up a range of opportunities for increasing dataset diversity, whilst averting the dangers of uncontrolled centralisation of heritage records. Fourth, foundation model approaches may be in time allow for more robust few shot monitoring potential, but their application would need to be coupled with robust and uncertainty estimation and governance mechanisms for heritage approaches. As such, the present study is therefore intended to be interpreted as a framework proposal, i.e. not as a statement of empirical superiority on the spot, for which the most important next phase needs to be prospective validation under real museum conditions.

9. Conclusion

Basohli paintings require a conservation strategy that is as materially sensitive and analytically precise as the objects themselves. Their combination of paper based supports, highly saturated chromatic surfaces, and dense culturally significant detail renders them insufficiently served by sporadic or purely manual monitoring approaches. By integrating calibrated imaging, environmental sensing, multimodal artificial intelligence, explainable analytical outputs, and conservator led interpretation, the framework proposed in this study offers a practical pathway toward real time preventive conservation within Indian museum collections.

A key strength of the proposed system lies in its modular design. Implementation may begin with relatively accessible components, such as standardized RGB imaging and microclimate logging, and subsequently expand toward more advanced capabilities, including spectral diagnostics and digital-twin integration, as institutional resources and technical capacity develop. The central argument of this article is therefore not that artificial intelligence should supplant conservation expertise, but rather that it can enhance the capacity of museums to detect change earlier, compare condition more reliably, and document conservation evidence more consistently, provided that such technologies remain object sensitive, transparent, and ethically governed. For Basohli paintings, this framework presents a credible and institutionally adaptable route from periodic inspection toward sustained, evidence based preservation.

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