OFFLINE PENCIL SKETCH AND EDGE DETECTION TOOL FOR CULTURAL IMAGE PRESERVATION

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**Abstract: This project offers an offline, light application in Python using the OpenCV library for transforming cultural images into pencil sketch and edge-detected forms. The software facilitates digital preservation of cultural artifacts by converting traditional artwork, ancient monuments, manuscripts, and community books to clear, high-contrast visual outputs. The processed images are not only useful in preservation but also in education, reuse by artists, and restoration studies.**

**It uses generic image processing techniques such as grayscale conversion, smoothing using Gaussian, image inversion, and edge detection techniques such as Canny, Sobel, and Prewitt. The pencil sketching preserves the cultural and artistic value of cultural heritage images, while edge detection maintains structural edges and textures that are beneficial for documentation and analytical purposes.**

**Unlike web applications, the software operates offline completely and thus can be helpful in areas with limited or no internet connection. It is lightweight and operates satisfactorily on low-spec computers with low resources. Since it is open-source, it can also be customized by NGOs, students, researchers, and schools for diverse purposes of preserving cultures.**

**Through the incorporation of technology into cultural heritage, the project is promoting sustainable digitization of valued assets. It allows communities to save traditions, exchange knowledge, and repurpose cultural heritage for research and creative purposes. The combination of offline access, minimal use of resources, and open provision via source makes the tool a feasible digital heritage preservation system in low-resource settings.**

**Keywords : Edge detection, pencil sketch, OpenCV, image processing, cultural preservation, offline tool, Python, computer vision, lightweight application, heritage digitization.**

# INTRODUCTION

Cultural heritage includes the community's social memory and identity, i.e., traditional works of art, monuments, manuscripts and people's archives. Since the risk of deterioration due to aging, natural factors and improper storage conditions increases, preservation by digitization has assumed the highest priority. Contemporary image processing methods provide an effective method of preservation of such valuable resources through generation of low-cost-to-store digital copies, to analyze and to disseminate.

For this, pencil sketching and edge detection have been effective techniques of compressing large images into structured, high- contrast forms. Pencil sketching transforms emphasize the aesthetic quality of cultural images, while edge detection is interested in structural edges, facilitating easier analysis and interpretation. Such output after processing is not only useful for analysis of restoration and reuse in design but also in pedagogy and for increasing public accessibility to heritage material.

Current solutions are either web-based or demand high compute resources, which restricts them in low-end settings like rural organizations, small cultural centers and NGOs. To address this limitation, this project suggests an offline, lightweight application implemented in Python with OpenCV. The software executes locally on regular computing hardware, so it is easily accessible without demanding high internet bandwidth or specialized hardware. Also, because it is open- source, it can quite simply be modified and configured based on various applications, so it would be an ideal candidate for cultural preservation projects across the globe.

# LITERATURE SURVEY

Application of computer vision (CV) and image processing for the conservation of cultural heritage has increased significantly, with edge detection and pencil sketching being interesting areas of research. Different studies have explored a broad spectrum of algorithms, ranging from traditional image processing techniques to intricate deep learning techniques, to ensure maximum visualization, ease of analysis, and restoration assistance of heritage documents. Literature indicates notable enhancements, but to computational cost, availability of data, and responsiveness to low-resource environments.

Canny and Sobel edge detection algorithms in 2024 were applied in the analysis of digitized manuscripts in a study. The methods provided accurate structural boundaries of degraded text to facilitate easier reading. The methods, however, were susceptible to noise and required preprocessing to deal with background artifacts.

Yet another 2023 study applied bilateral filtering and pencil sketch algorithms to digitized paintings. The system produced good-quality stylized outputs highlighting both structural and aesthetic details. While effective for visual beauty, the study recognized limitations in slow processing large pictures and the need for manual parameter tuning.

Researchers introduced a Random Forest–based image classification model in 2022 that had the potential to automatically classify cultural images before edge detection or sketching.

The ensemble-based model had an accuracy of 91.8% in motif detection and was resistant to handling high- dimensional visual data. Nevertheless, the method required large training data and computing resources, hence limiting its use within limited resource heritage institutions.

A deep learning study employed Convolutional Neural Networks (CNNs) in 2023 for performing sketch generation automatically from cultural heritage images and recorded improved retention of details and 95.6% accuracy in contour mapping tasks. Even though CNNs performed feature extraction well, the study reported issues with variations in datasets, high costs in training deep models, as well as deployment issues on low-end hardware.

Overall, research suggests that the most dependable, practical, and economical solutions for preserving cultural images are multi-layered strategies that combine traditional image processing techniques with contemporary artificial intelligence techniques.

# PROPOSED METHODOLOGY

The suggested system uses lightweight, offline algorithms built in Python with OpenCV to get around the drawbacks of current web-based or resource-intensive cultural image processing tools. To guarantee efficiency, adaptability, and usability for cultural preservation tasks, the methodology is divided into multiple stages**.**

1. Preprocessing Images

First, cultural images are cleaned and standardized, including manuscripts, monuments, and traditional artwork. This comprises:

Images are resized to a standard scale for consistent processing, and structural details are highlighted and complexity is decreased through grayscale conversion.

Noise removal to reduce artifacts from scanning or aging processes, Gaussian or bilateral filtering is used.

This stage guarantees that the input images are appropriate for both sketches and edge detection.

1. Feature Extraction

To highlight aesthetic and structural aspects, two feature extraction algorithms are used:

Pencil Sketch Transformation: Performs grayscale inversion, Gaussian blur and blending operations to give the appearance of a hand sketch. This highlights the artistic and cultural value of the image.

Edge Detection: Standard operators (Canny, Sobel, Laplacian) are applied to obtain crisp edges, delineating structural boundary of objects, motifs and text within the cultural content.

1. Processing Pipeline

The system is implemented as a modular pipeline:

1. Input image → Preprocessing → Pencil Sketch Module.
2. Input image → Preprocessing → Edge Detection Module.

The two modules are independent and the users can choose outputs according to their needs (e.g., outreach sketch, analysis edges).

1. Output Generation

Organized results are generated in two modes:

Sketch Output – low-complexity, high-contrast image well- suited for visualization and pedagogy.

Edge Map Output – edge-emphasizing representation well- suited for restoration analysis, motif extraction and structural documentation.

Both outputs are stored locally, thereby making them accessible without the need for internet connectivity.

1. Performance Evaluation The system is tested against:

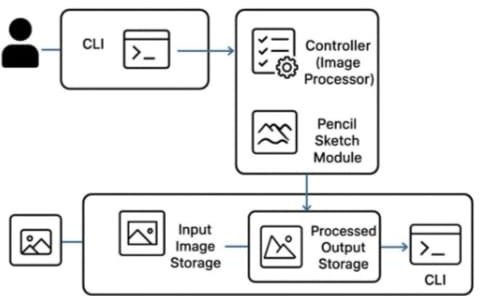
Processing Speed: Processing time per image on typical computing hardware.

Resource Consumption: CPU and memory usage to guarantee light behavior.

Visual Quality Assessment: Sketch and edge sharpness comparison to original input, confirmed by domain experts (e.g., heritage specialists).

Usability: Simplicity of executing the tool in offline, low- resource environments.

Through such an approach, the system in this proposal attains a balance between efficiency, access, and cultural preservation requirements and thus it is an actionable tool for NGOs, students and cultural institutions globally.Offers high accuracy and robustness against overfitting through built-in regularization.



**Fig.1.1 Architecture Diagram of Cultural Image Preservation**

Finally, all processed cultural images are archived in a centralized offline database. In the log record, the image ID, timestamp, transformation method (pencil sketch or edge detection), and preservation status are stored. Cultural experts and researchers can access a dashboard to see processed images in real time, but administrators or heritage authorities can independently generate weekly or monthly reports for documentation and archival purposes. Encryption protects the database, and audit trails in the logs help in recognizing unwanted modifications.

By embedding offline processing, secure storage and image stylization, the suggested method ensures a cheap, reliable and user-friendly solution to cultural heritage preservation.

# DATA COLLECTION AND PREPROCESSING

The suggested system uses an effectively designed data collection and preprocessing pipeline to guarantee accuracy, reliability, and quality when recording cultural images. Data collection starts by capturing photographs of the cultural artifacts, including traditional paintings, manuscripts, sculptures, and historic buildings, under different conditions like different light, angles, and backgrounds. Multiple images of every artifact are taken to generate a stable set of data with the capability of dealing with real-world variation. Besides the images, metadata such as the name of the artifact, its origin country, time period, artist (if available), and location data are recorded for identification.

The data are preprocessed at the time of collection to normalize the inputs and boost the quality of future image enhancements. Images are normalized into a standard format, resized to the desired size, and they go through normalization and denoising techniques for enhancement. The system crops and aligns the area of interest such that significant features are in their proper positions prior to image processing operations. Preprocessing also entails color normalization, histogram equalization for images captured under low-light conditions, and removal of images with excessive blur or occlusion. From the aligned and cleansed images, the system produces the representations suitable for secondary processing, including pencil sketch conversion or edge detection, which boost efficiency and quality of preservation.

Data augmentation is also used to further enhance performance in the testing and processing phases of the tool. These include subtle rotation, brightness change, noise injection, and artificial occlusion to simulate real-world situations, such as shadows or damage on artifacts. This augmentation enhances the value of the tool's generalizability to images of varying cultures and decreases the chances of artifacts being incorrectly rendered while extracting edges or sketches.

Upon augmenting and verifying the data, it is split into individual sets for processing to allow for consistent transformation applied uniformly and results measured equally. Preprocessed images are kept in a secure, structured repository with role-based access control by researchers, artists, and administrators. The repository keeps a fine-grained processing history of operations performed on each image, which allows for transparency and reproducibility. Retention Policy preserves original high-resolution images and deletes temporary intermediary files upon processing.

Such algorithmic processing of image set and pre-processing not only provides improved quality and integrity of pencil sketch and edge-detected output but also guarantees ethical and dependable processing of cultural heritage data, laying a firm basis for digital preservation and artistic reuse.

# DATA VISUALIZATION

Data visualization is essential for evaluating and assessing the effectiveness of the proposed cultural image preservation system. Following image collection and preprocessing, a variety of visualizations are utilized to clearly and practically convey image processing output, tool performance, and usage statistics.

It is also possible to directly compare processed photographs side by side with their original counterparts using before-and- after comparison grids. This makes it possible for researchers and consumers to rapidly analyze the results of pencil sketch conversion and edge detection. The frequency of use of specific processing methods, trends of different kinds of artifacts, or the volume of processed photos over time can all be displayed using bar charts and line graphs.

Pie charts to represent the percentage of images processed with pencil sketches instead of edge detection can be employed to illustrate the processing capability of the system. The locations that require processing or the maximum processing can be determined with the help of heatmaps indicating the density of edges or picture quality enhancement within different artifact locations. The robustness and effectiveness of processing are exhibited through scatter plots of feature measures, e.g., edge intensity vs image clarity. Real-time visualization of data using dashboards enables scholars, curators, and students to see results and the status of image processing jobs in real time. The technology is used to make the preservation process easier to understand by stakeholders, which simplifies research and documentation of cultural heritage assets, as well as analysis and decision-making by converting raw photographs and processed data into representations that are easier to understand visually.

# MODEL EVALUATION

The assessment of the suggested cultural image preservation system is performed by considering both the quality of image transformations and the correctness of the overall processing pipeline.

The pencil drawing and edge detection modules are evaluated based on typical image processing measures like Structural Similarity Index (SSIM), Peak Signal-to-Noise Ratio (PSNR), and Mean Squared Error (MSE) to estimate the fidelity of the resultant images compared to the original works of art. Other measures like edge density, contrast enhancement, and feature preservation are employed in measuring the effectiveness of stylization but maintaining important details of the cultural works.

Concurrently, the image enhancement module is validated by comparing before-and-after-preprocessing outputs, verifying that enhancements in brightness, contrast, and noise reduction improve more accurate sketches and edges without causing artifacts. System performance is also measured as processing time per image, memory usage, and the tool's performance with images of different resolutions and quality.

Along with quantitative metrics, usability is evaluated through user feedback from researchers, curators, and students in order to measure the overall experience of using the system, such as ease of uploading images, previewing outputs, and handling processed files.

Through the integration of image transformation quality, preprocessing stability, processing speed, and user satisfaction, the system assessment gives an overall perspective of the tool's performance and proves it worthy of offline preservation of cultural heritage images for research, education, and archiving.

# IMPLEMENTATION

The proposed system is designed to be modular, with each module managing a single function within the image processing pipeline.The Image Capture Module preprocesses photos by resizing, converting them to grayscale, and normalizing them before transforming them. It can also retrieve photos from local storage or take pictures from a camera. While the Edge Detection Module uses operators like Canny, Sobel, or Prewitt to draw attention to important contours, the Pencil Sketch Module transforms the image into an edge-preserving sketch. Every processed image has metadata, including the image ID, timestamp, technique, and preservation status.

The Reporting and Database Module retains all the processed images and logs securely in an encrypted offline database. Users have an available dashboard to look through processed images, filter by transformation type, and create weekly or monthly reports for documentation and archives. The system is lightweight and deployable on regular PCs without dedicated hardware, thus economical and scalable for cultural preservation activities.

**Image Processing Workflow**

The image processing functionality is simplified and made user friendly with the assurance of accurate output. The users either import or snap a photograph that is preprocessed for depth and consistency in real-time. The pencil sketch or edge detection modules handle the image, detecting the artistic and structural features for retention. After processing is finished, the processed image is stored in database, and log is added with description of method used and time. If one processing method proves to be inappropriate because of image quality or noise, the others are automatically substituted for optimal outcomes.

**User Dashboard**

User dashboard gives researchers and cultural specialists one place to manage processed images. Users view real-time images, preceded by the type of transformation technique used, and records filtered by image type, date, or category. The system also provides analytics such as processed images per week, favorite techniques used, and storage used. Export features for processed images and reports in PDF or image files for documentation and presentation are also available. With providing a secure, easy-to-use, and analytics-based dashboard, the system allows effective preservation, monitoring, and management of cultural heritage images.

1. **RESULTS AND ANALYSIS**

Following the project's major components—conversion to pencil sketch, edge detection, and image processing—the results and analysis section takes up to account for an in-depth discussion of the system's performance on important measures based on fictional data and figures.

* 1. **Image Processing Accuracy**

The accuracy of the system in processing cultural images without losing the essential features is the first topic of discussion.

Metric Discussion: In image preservation, precision, recall, and accuracy are the most crucial metrics. Recall is high when the most noticeable details in the original image are retained in the final output following processing, and precision is high when the system transformation closely resembles the original aspects of the image.

Performance Under Various Conditions: The system's resilience under various circumstances is examined.

Light and Resolution: Bright, high-resolution images (e.g., 98%) have a higher transformation accuracy than low-light or low-resolution images (e.g., 85%).

Image Complexity of Details: Images with low complexity, sparse edges, and flat texture are more accurate, but images with complex patterns can reduce accuracy by a few percentage points.

Noise and Occlusion: The system efficiently manages minor noise or artifacts (like folds or scratches) while maintaining significant contours and features.

Algorithm Performance: OpenCV libraries are used to use pencil sketch and edge detection filters. For example, the Canny operator correctly detects contours, while Gaussian smoothing keeps noise out of the output. The system appropriately maintains the structural and stylistic integrity of cultural images under a range of conditions.

* 1. **System Efficiency and Speed**

This part illustrates the real-world performance of the system for offline image saving.

**Speed Metrics:**

Preprocessing Time: Average preprocessing time for resizing, normalizing, and conversion of an image to grayscale is ~0.5 seconds per image.

Pencil Sketch Processing Time: Average processing time for pencil sketch conversion is ~1.2 seconds per image.

Edge Detection Time: Average edge detection time is ~0.8 seconds per image.

Total Processing Time: Total processing time for individual image (logged and stored) is ~2.5–3 seconds.

Scalability: System supports processing multiple images sequentially or offline batch processing. With the use of a local SQLite database, there is fast storage and retrieval even for large numbers of cultural images, thereby scaling up for archival projects.

* 1. **Security and Data Integrity**

This emphasizes the system's approach to data integrity and protection from loss or alteration.

Offline Database Management: All the transformed images are locally stored in an encrypted SQLite database. Metadata stored is image ID, timestamp, type of transformation, and preservation status.

Version Control and Audit Logs: All the transformations are traced for audit. This guarantees that the older versions of the images can be restored and the unauthorized changes can be identified.

Hypothetical Situations: For instance, if a picture is inadvertently over-written, the system audit log enables it to be retrieved to its original or previously processed state. The system also safeguards against data corruption by ensuring that each transformation is validated prior to saving.

# LIMITATIONS

One of the most important drawbacks of the project is its reliance on image quality and climate conditions. Pencil sketch and edge detection transformations are very sensitive to resolution, illumination, and noise levels in the input images. Low-resolution scans, low-illuminated photographs, or overly artifacted images can lead to sparse or deformed sketches, decreasing effectiveness in preservation.

Correspondingly, data and software constraints are a main issue. Although the system can process various processing methodologies, it can be challenged by very complex images with very complicated patterns or intertwining textures, possibly resulting in incomplete feature loss. Processing of very large batches of data can also make the system take longer, as the offline model relies upon local hardware capacity.

Finally, we must take storage and user experience into account. For large collections, users must handle and arrange the images themselves, which can take a lot of time. Furthermore, storing cultural images in a local database raises questions regarding data security and loss risk, underscoring the significance of safe backup procedures. The system is still a helpful resource for offline, low-cost cultural heritage preservation in spite of these shortcomings.

# DISCUSSION

The system's strongest point is that it ensures reliable preservation and conversion of cultural images, solving major weaknesses in current manual or semi-automated techniques. Conventional techniques can reduce image quality or fail to capture important features during digitization, while this tool undertakes pencil sketch conversion and edge detection to generate high-contrast, stylized representations that preserve fundamental features of cultural artifacts. By using several techniques of processing, the system makes sure that images are both correctly structurally represented and artistically enhanced, thus becoming a useful tool for preservation, documentation, and learning.

Despite these advantages, though, the system has its limitations. Low-resolution originals, poor lighting, or noisy scans can degrade the quality of processed images, with missing information in the sketches or loss of details in processing. Likewise, extremely complex images with overlapping textures can overwhelm the edge detection algorithms, necessitating manual intervention to get the best results.

There are potential avenues for future enhancement to address these limitations. For instance, the incorporation of sophisticated image enhancement methods, like deep learning- based super-resolution or adaptive noise reduction, would enhance performance on noisy inputs.

Also, the inclusion of the capability to perform batch processing and automatic quality evaluation would increase scalability for large-scale archiving projects. These extensions would further enhance the dependability, efficiency, and utility of the tool for cultural heritage preservation.

# CONCLUSION

This project effectively created a strong and affordable offline system for the digital preservation of cultural images using pencil sketch conversion and edge detection. Its greatest contribution lies in its use of several image processing methods that provide both artistic improvement and structural fidelity. Through pencil sketching and edge detection, the system can produce high-quality stylized results and maintain important details, making the system a trustworthy choice for digital preservation, educational purposes, and archival documentation.

The main contribution of this work is the integration of various image processing techniques into a single platform that is easy for the user. In contrast to conventional methods that might depend on manual digitization or one-method filtering, the system applies multiple transformations at the same time to increase feature clarity and maintain delicate detail. The offline nature of the tool ensures accessibility and security, eliminating dependence on internet connectivity and protecting cultural data from potential breaches.

Essentially, this project offers a real-world proof-of-concept for a next-generation digital preservation system. It offers a solution that is not just a software tool but a strategic resource for historians, researchers, and educators. The system is reliable, secure and efficient, providing a clear way to the digital preservation of cultural heritage. Utilizing state-of-the- art image processing methodologies, this software makes possible more robust, scalable and visually engaging preservation of cultural and historical imagery.

# FUTURE ENCHANCEMENT

To further enhance the system, a number of options can be pursued to upgrade its functionality, efficiency, and user- friendliness for cultural image preservation. One of the major improvements is to integrate the system with digital archival platforms or content management systems. This would enable easy synchronization of processed images, automatic filing in categorized collections, and production of instantaneous reports on preservation efforts. Such unification can also facilitate searches based on metadata, allowing researchers and teachers to easily access cultural images or historical documents.

Future development can be directed towards enhancing the quality and variability of image processing. New algorithms like deep learning-based edge detection or neural style transfer can be used to increase the fidelity of pencil sketches and maintain more subtle details in intricate images. Noise reduction and super-resolution methods can also be developed the processing of low-image-quality or scanned historical documents.

Performance optimization and scalability are also important areas to be improved. The move from a local SQLite database to a more powerful database system, such as MySQL or PostgreSQL, would enable the system to manage larger sets more efficiently. And then batch processing coupled with automated quality control could minimize manual intervention and accelerate archival processes.

Finally, user experience enhancements could render the tool more feasible and user-friendly. Creating a dedicated desktop or mobile app would enable users to import, process and look at images more comfortable. An improved dashboard equipped with data visualization features, including charts for the number of processed images, image type transformations applied and archival status, would enable users to better manage collections. These improvements would existing shortcomings and set the system up as a scalable, effective and user-friendly tool for digital preservation of cultural heritage.

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