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Forensic Face Sketch Construction and Recognition (FFSCR)

An AI-Assisted Workflow for Facial Sketch Generation and Candidate Image Retrieval

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Abstract: ***Facial sketch-based investigation is used when a photograph of a person of interest is unavailable and an eyewitness description is the primary source of visual information. Traditional sketch preparation and manual comparison can be time-consuming, and matching a sketch against photographs is challenging because of differences in texture, lighting, and representation. This paper presents Forensic Face Sketch Construction and Recognition (FFSCR), an academic prototype that combines structured facial-attribute input, AI-assisted sketch generation, image preprocessing, feature extraction, similarity-based candidate ranking, and suspect-record management. The prototype is described using React and TypeScript for the interface, Python and FastAPI for backend services, OpenCV and NumPy for image processing, and SQLite for structured storage. The project materials describe HOG and spatial-density features for image representation and cosine similarity as a possible matching measure. Generated sketches and ranked candidates are intended to support investigator review rather than establish identity. The paper outlines the architecture, workflow, algorithms, test plan, limitations, and future improvements. Quantitative recognition performance is not claimed because a labelled evaluation dataset and reproducible measurements have not yet been documented.***

Keywords: ***Forensic sketch, face sketch recognition, sketch-to-photo retrieval, AI image generation, computer vision, HOG, similarity matching, human review.***

I. INTRODUCTION

In investigations where a clear facial photograph or video frame is unavailable, an eyewitness may provide a description of a person's facial characteristics. Such descriptions can be translated into a hand-drawn or computer-generated facial composite. The resulting sketch can help communicate a visual description, but it may not reproduce the person's appearance exactly. Sketch-to-photo matching is also difficult because sketches and photographs differ in colour, texture, shading, and image formation.

Computer vision research has explored synthesis and recognition across sketch and photograph modalities. Wang and Tang demonstrated photo-sketch synthesis and recognition using a multiscale model [1]. Klare and Jain investigated matching forensic sketches to mug-shot photographs [2], while component-based representations have also been explored for composite-sketch matching [3]. Deep-learning approaches have investigated transfer learning and synthetic data to address limited sketch datasets [4].

FFSCR integrates facial attribute entry, AI-assisted sketch generation, image processing, candidate-photo comparison, and result presentation into a single prototype workflow. The system is designed to assist an authorized user by organizing candidate images and similarity scores; it is not intended to make definitive identity decisions.

II. LITERATURE REVIEW

A. Photo–Sketch Synthesis and Recognition

Wang and Tang proposed a multiscale Markov Random Field approach for face photo-sketch synthesis and recognition, including searching a photo database using a sketch query [1]. Their work highlights the importance of learning relationships between local facial structures across image modalities.

B. Forensic Sketch Matching

Klare and Jain studied the matching of forensic sketches with mug-shot photographs and showed that the task is distinct from matching ordinary face photographs [2]. Han et al. proposed a component-based representation for comparing composite sketches and face photographs, using facial components and landmark-based processing [3].

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C. Deep Learning Approaches

Galea and Farrugia examined deep-learning-based photo-sketch recognition and discussed the difficulty of limited real forensic-sketch data [4]. Recent work has also investigated latent representations that reduce the visual gap between sketch and photograph domains [5].

D. Research Gap

Existing research investigates synthesis, recognition, feature learning, and sketch-photo retrieval as individual technical problems. FFSCR's project-level contribution is an integrated prototype workflow that collects facial attributes, requests sketch generation, preprocesses the result, compares it with stored image records, and presents ranked candidates. The practical usefulness of the integration must be assessed through controlled testing, including false matches, missed matches, and retrieval metrics.

III. PROBLEM STATEMENT AND OBJECTIVES

A. Problem Statement

Preparing facial composites from witness descriptions and searching large image collections manually can require substantial effort. Sketches and photographs have different visual characteristics, making direct comparison difficult. The project therefore aims to develop a software system that supports AI-assisted sketch construction, suspect-image management, and similarity-based candidate retrieval

B. Existing System and Limitations

Existing approach	Limitations
Manual sketch preparation and separate image search	Time-consuming; dependent on witness recall and artist interpretation
Manual sketch-to-photo comparison	Difficult when image styles, lighting, or quality differ
Separate tools for sketching, storage, and matching	Repeated data entry and fragmented workflow
Automated recognition tools	May produce false matches; require suitable datasets and validation

C. Objectives

1) Collect facial characteristics through a structured interface.
2) Generate prompts for AI-assisted sketch construction.
3) Produce a sketch through the configured image-generation service.
4) Preprocess images and extract numerical features.
5) Store suspect records and image references.
6) Compare a query sketch with stored photographs and rank candidates.
7) Present scores and candidate results for human review.

IV. SYSTEM ARCHITECTURE AND DESIGN

FFSCR follows a modular client-server design. The frontend collects facial attributes, displays generated sketches, and presents candidate results. The backend handles API requests and application logic. Image-processing functions prepare images and calculate feature representations. The database stores suspect records and associated image references. The configured AI generation service is called to produce a sketch from the descriptive prompt.

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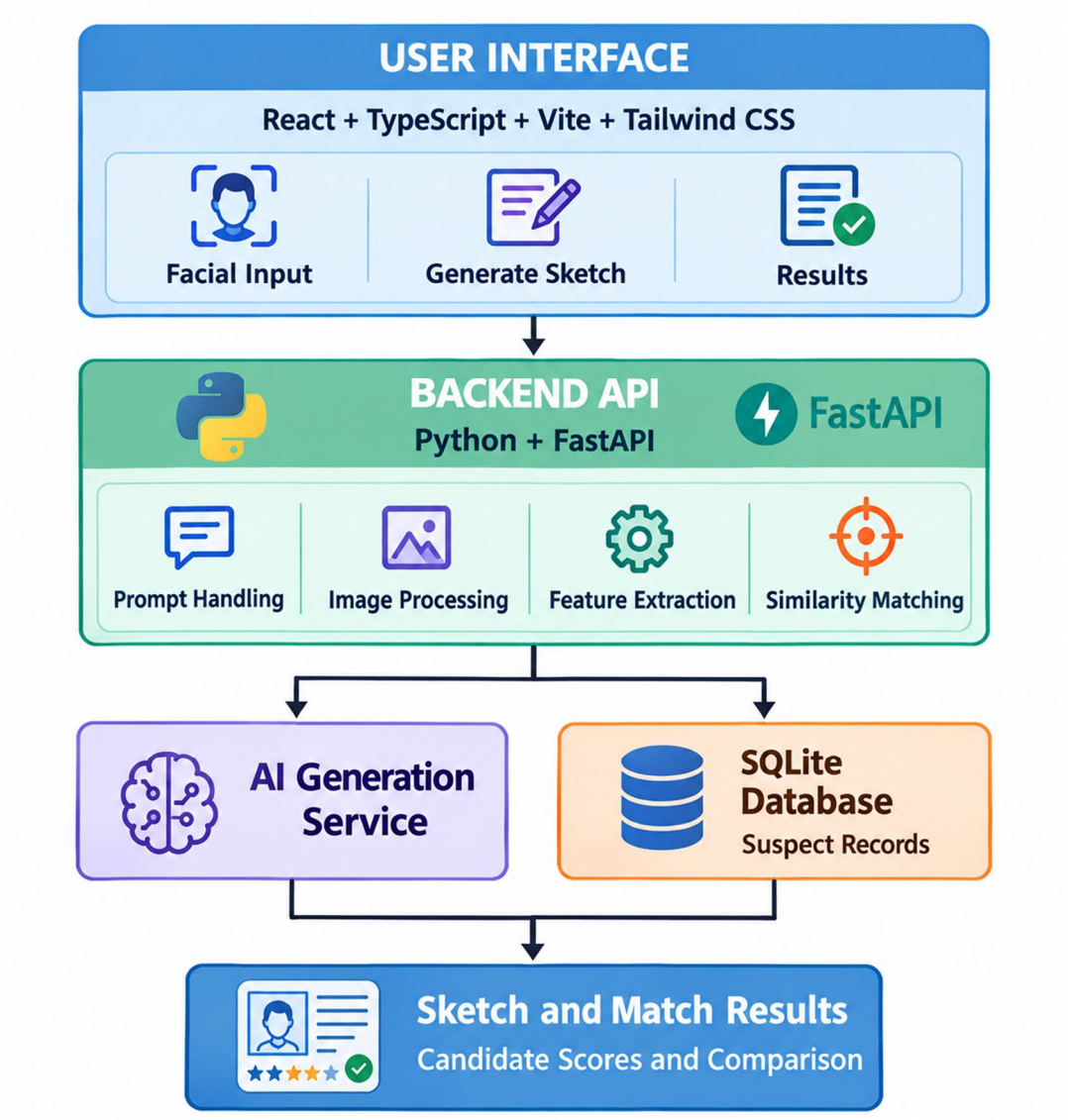


Fig. 1. FFSCR system architecture showing frontend, backend API, AI generation, database, and matching-result components.

Component	Technology / responsibility
Frontend	React, TypeScript, Vite, Tailwind CSS; facial input, sketch view, results
Backend	Python, FastAPI; API handling and application logic
Image processing	OpenCV, NumPy, Pillow; image loading, resizing, grayscale conversion, feature extraction
AI generation	Configured image-generation service; prompt-based sketch generation
Database	SQLite; structured suspect and image-reference records
Matching	Feature comparison and candidate ranking; project materials describe HOG and spatial-density features

A. Main Use Cases

The user enters facial attributes, generates a sketch, views or saves the generated image, manages suspect records, starts image matching, views candidate results, and may prepare a report if the reporting module is enabled. The intended workflow is an assistance tool for authorized investigative review.

B. Conceptual Data Model

The conceptual data model includes case records, sketches, suspect records, and match-result records. A case may contain multiple sketches; each sketch may generate multiple candidate match results; a suspect may be referenced by multiple match results. Actual database fields and cardinalities should be checked against the final SQLite schema.

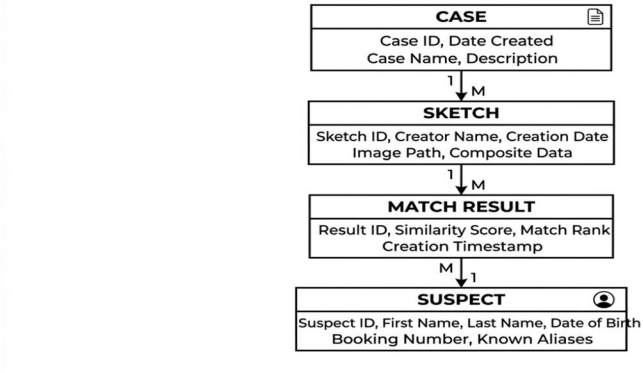


Fig. 2. Conceptual entity relationship diagram reproduced from the project report.

V. METHODOLOGY AND ALGORITHMS

A. Facial Attribute Collection and Prompt Construction

The interface collects descriptive attributes such as face shape, eyes, nose, lips, hairstyle, and facial hair. The selected attributes are assembled into a textual prompt that requests a forensic-style monochrome sketch. The prompt may specify a neutral background and pencil or graphite appearance. The generated image must be reviewed because an image-generation model may introduce details not included in the description.

B. AI-Assisted Sketch Generation

The project report identifies a frontend generation flow using Puter.js and a text-to-image call. A request is submitted to the configured service, and the returned image is displayed if generation succeeds. The workflow depends on network availability, service access, and any applicable usage limits. The active generation path should be verified before describing any alternate backend generator as an automatic fallback.

C. Image Preprocessing

Preprocessing prepares images for comparison. The described operations include image validation, loading, grayscale conversion, resizing to a consistent dimension, and optional contrast enhancement. These operations reduce variation in input format and size. Additional operations should be reported as implemented only when confirmed in the code and tested.

D. Feature Extraction

The project materials describe Histogram of Oriented Gradients (HOG) and spatial-density features. HOG summarizes local gradient orientations and can represent edge and contour structure [6]. Spatial-density features summarize feature information over image regions. The feature vector is the numerical representation used by the matching stage.

E. Similarity Matching

The system compares the query-sketch representation with representations of candidate photographs. Cosine similarity is described as a possible measure:

$$\textbf{cosine_similarity}(A,B) = (A \cdot B) / (||A||\ ||B||)$$

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where A and B are feature vectors, A · B is their dot product, and ||A|| and ||B|| are their magnitudes. Candidates can be sorted by score. A threshold may be used to present possible matches or a no-match result, but the threshold and any score-to-percentage conversion must follow the actual implementation. A high score is not proof of identity.

F. Matching Algorithm

Select or upload a query sketch.
Validate the image and apply configured preprocessing.
Extract the query feature vector.
Retrieve candidate records from the database.
Extract or load each candidate feature representation.
Calculate similarity scores.
Sort candidates by score.
Apply the configured threshold, if implemented.
Display ranked candidates and scores for human review.

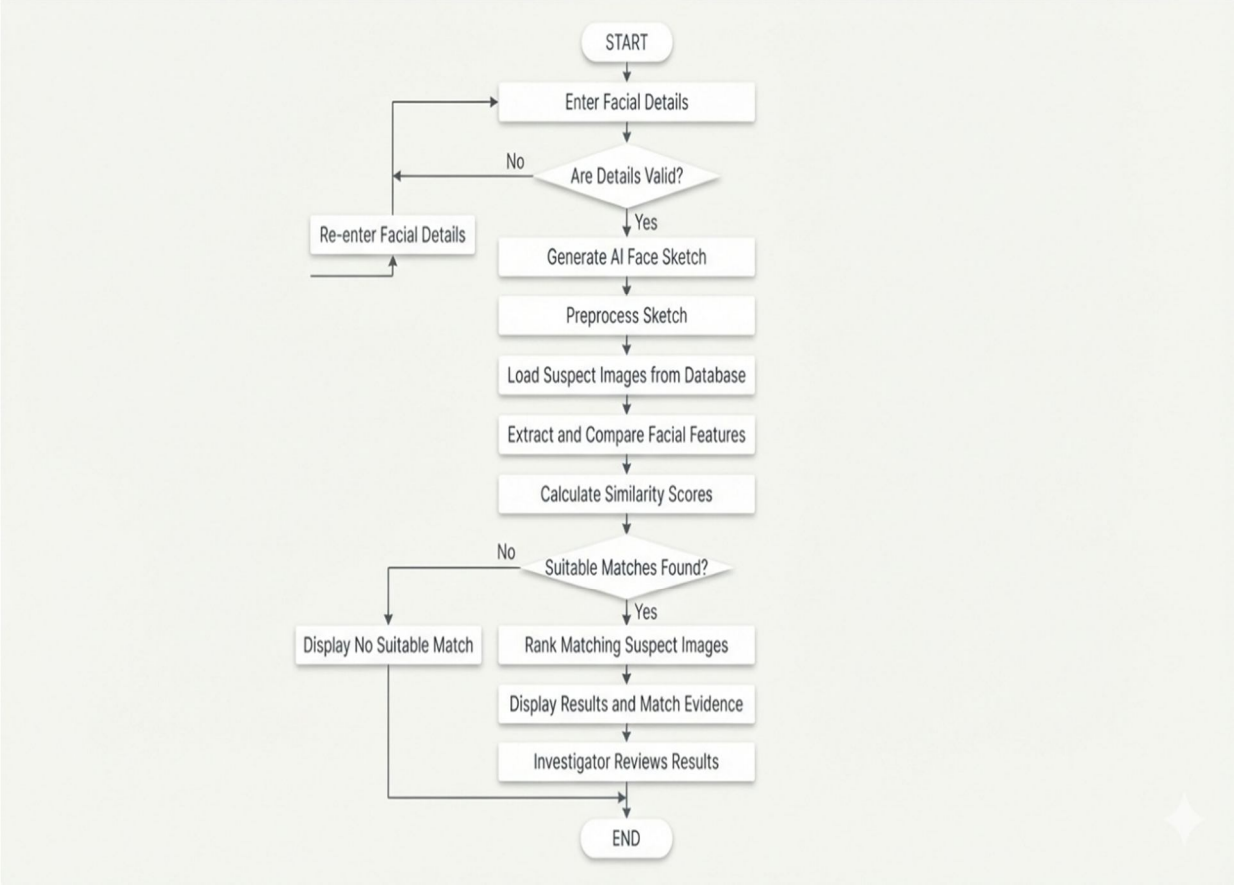


Fig. 3. Matching process flow chart provided in the project report.

VI. IMPLEMENTATION

The frontend is described as React, TypeScript, Vite, and Tailwind CSS. It provides the facial-attribute form, sketch-generation interaction, and result presentation. The backend uses Python and FastAPI for API services and application logic. Image handling and feature extraction are associated with OpenCV, NumPy, and Pillow. SQLite is identified as the database technology.

The project materials describe suspect records and image references as database-managed data. Images may be stored as files while their paths or references are retained in the database. The exact table names, fields, feature-vector storage format, and API routes should be aligned with the active implementation before final publication.

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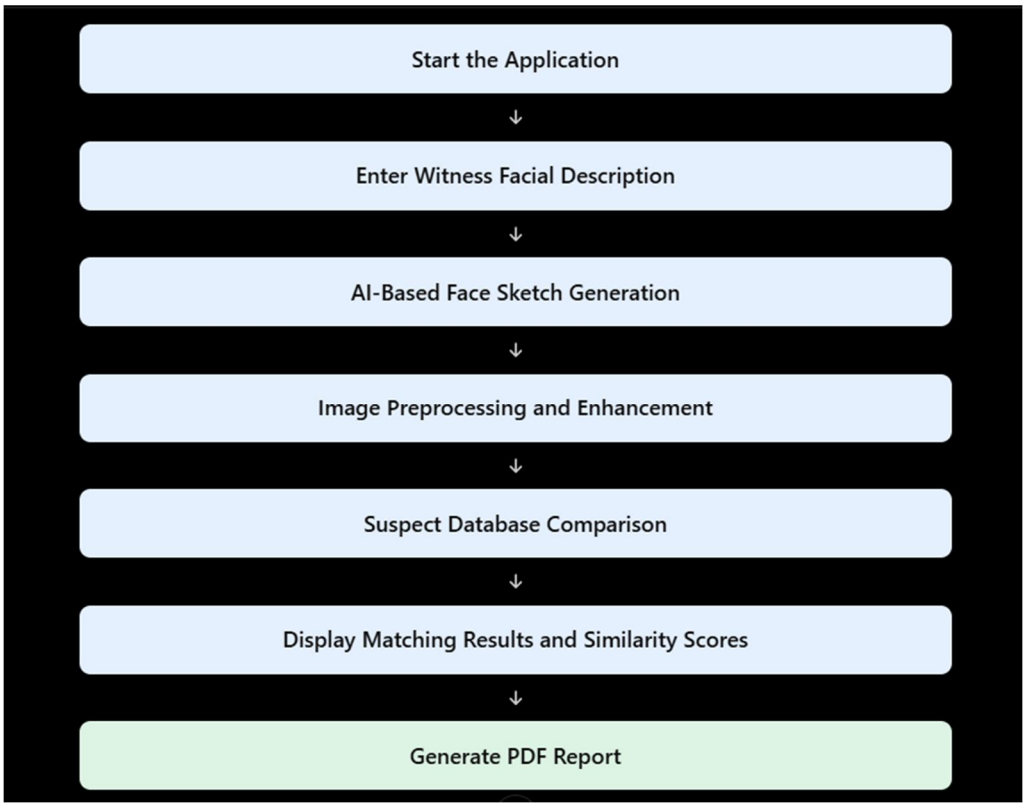


Fig. 4. High-level project workflow: input, sketch generation, preprocessing, comparison, results, and report output.

VII. TESTING AND EVALUATION

Testing should verify individual functions, module integration, and the complete workflow. The project report lists the following planned test cases. Since the report does not provide execution evidence for all tests, the table presents expected outcomes rather than claiming that they passed.

Test ID	Test scenario	Expected result
UT-01	Enter facial attributes	Valid descriptive prompt is created
UT-02	Load valid image	Image loads successfully
UT-03	Upload invalid image	Controlled error is displayed
UT-04	Extract image features	Valid feature representation is returned
UT-05	Calculate similarity	Numerical score is produced
IT-01	Frontend to AI service	Sketch returned or clear error shown
IT-02	Frontend to backend	API returns expected response
IT-03	Backend to database	Records stored and retrieved correctly
ST-01	Generate sketch	Sketch displayed when generation succeeds
ST-03	Compare query image	Candidate scores returned
ST-04	Empty repository search	Empty result handled appropriately
ST-06	Complete workflow	Connected modules operate as expected

A labelled dataset should be used for quantitative evaluation. Recommended metrics include precision, recall, false acceptance rate (FAR), false rejection rate (FRR), and top-k retrieval accuracy. Tests should record input, expected output, observed output, environment, and PASS/FAIL status. No recognition-accuracy percentage is reported in this paper because documented measurements are not available.

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VIII. RESULTS AND DISCUSSION

The prototype design integrates the principal stages of a sketch-based retrieval workflow: facial-attribute entry, AI-assisted generation, image preprocessing, feature extraction, database retrieval, similarity calculation, ranking, and result display. The architecture provides a common interface for these operations and can organize candidate results for further review.

The technical challenge remains the modality gap between sketches and photographs. Similarity scores can be influenced by image quality, sketch style, pose, lighting, preprocessing, feature representation, and the composition of the gallery. Therefore, a ranked list should be interpreted as candidate retrieval, not identification. A meaningful evaluation requires a labelled dataset, repeated experiments, and documented metrics.

IX. LIMITATIONS

1) Sketch quality depends on the witness description and the configured generation model.
2) Generated sketches may contain details not present in the original description.
3) Matching reliability depends on image quality, feature representation, and the candidate database.
4) The report does not provide a documented labelled benchmark or measured recognition accuracy.
5) Similarity scores do not establish identity and may produce false matches.
6) The active image-generation and matching implementations should be verified against the final source code.
7) Real-world forensic use would require extensive validation, security controls, privacy safeguards, and professional oversight.

X. FUTURE ENHANCEMENTS

1) Evaluate stronger sketch-photo matching models and learned representations.
2) Use a properly labelled dataset and report precision, recall, FAR, FRR, and top-k retrieval accuracy.
3) Improve prompt controls and support multilingual witness descriptions.
4) Add secure role-based access, audit logs, encryption, and controlled retention of sensitive records.
5) Improve case-based report generation with images, candidate scores, and review notes.
6) Explore model-assisted feature comparison while maintaining human oversight.
7) Test the system under varied image quality, pose, lighting, and sketch styles.

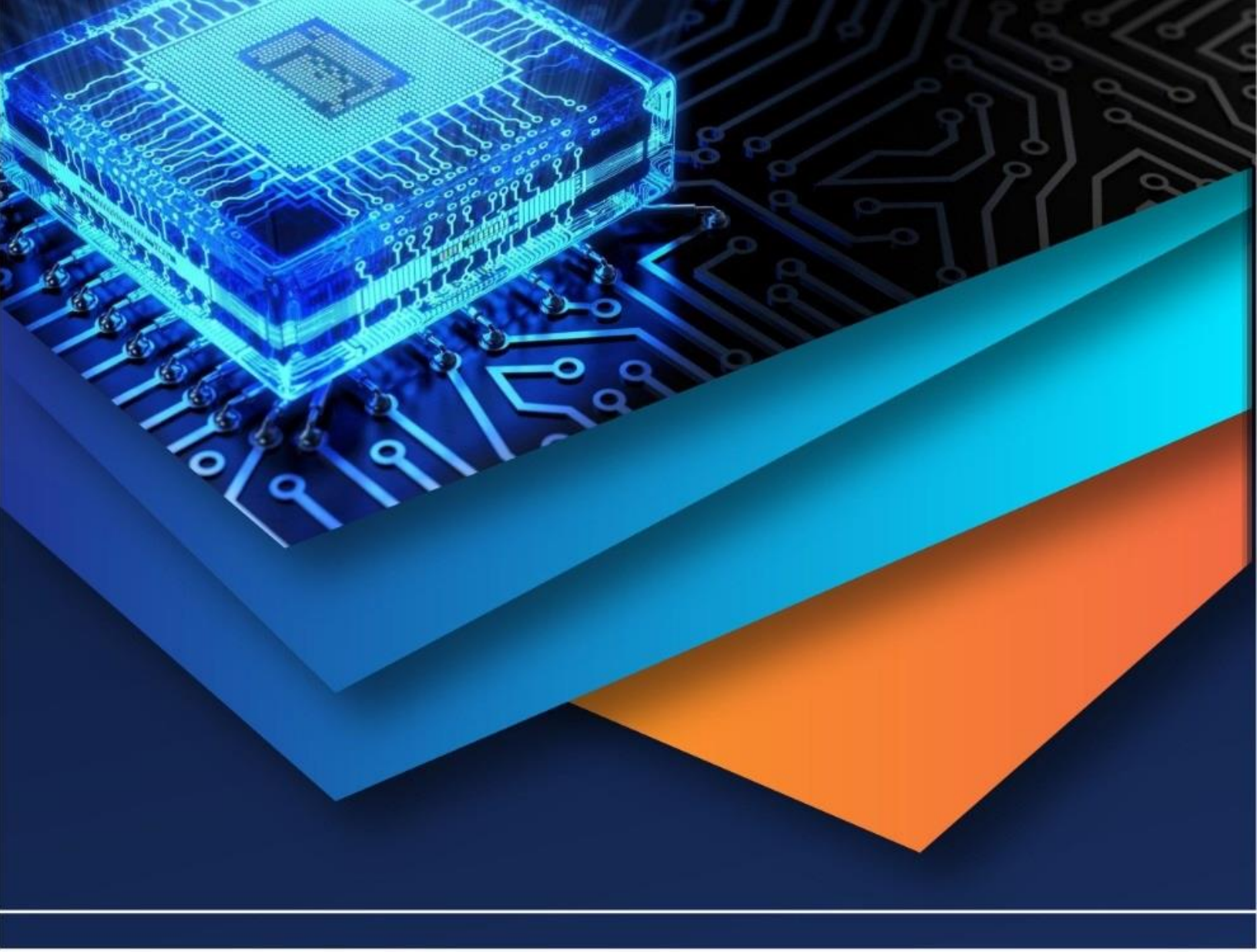
XI. CONCLUSION

Forensic Face Sketch Construction and Recognition (FFSCR) presents an academic prototype that integrates facial-attribute collection, AI-assisted sketch generation, image preprocessing, feature extraction, database management, and similarity-based candidate retrieval. The project combines a modern web interface with backend services and computer-vision processing to organize the sketch-to-photo search workflow. Its results are intended to assist investigators by presenting possible candidates for review. Further work is required to verify the active implementation, evaluate the system using a labelled dataset, quantify retrieval performance, and strengthen security and privacy. The prototype should not be used as the sole basis for identity determination.

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