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DermalSense AI: An Explainable Framework for Personalized Skincare Recommendation

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Abstract
Personalized skincare has become increasingly important due to the growing demand for intelligent solutions that assist users in selecting skincare products based on their individual skin characteristics. Conventional skincare applications often provide generalized recommendations without considering ingredient compatibility, skin progression, or personalized routine management. This paper presents Dermal Sense AI, an explainable personalized skincare recommendation system that integrates rule-based skin analysis, ingredient safety assessment, personalized routine generation, progress monitoring, and adaptive recommendation within a unified web-based platform. The proposed framework utilizes browser-based facial image capture, image heuristic analysis, and user-provided skin parameters to classify skin into five categories: Dry, Oily, Combination, Sensitive, and Normal. Based on the identified skin profile, the system recommends suitable skincare products from the Skin SAFE dataset containing over 50,000 products while applying ingredient safety filters to exclude incompatible formulations. In addition, the framework generates personalized morning and evening skincare routines, tracks routine completion, visualizes skin progress through comparative analysis and interactive charts, and incorporates a seven-day feedback mechanism that continuously refines future recommendations based on user experience. A dedicated safety module performs ingredient compatibility verification and suggests safer alternatives when adverse skin reactions are reported. The system is implemented using Next.js, TypeScript, Prisma ORM, SQLite, and modern web technologies to provide a scalable, responsive, and user-friendly architecture. Experimental evaluation demonstrates that the proposed framework improves recommendation personalization, enhances user engagement through continuous progress monitoring, and promotes safer skincare product selection by combining explainable decision-making with adaptive recommendation strategies. The proposed system offers an effective and practical solution for intelligent personalized digital skincare management.

Index Terms— *Personalized Skincare, Rule-Based Skin Analysis, Explainable Artificial Intelligence (XAI), Skincare Recommendation System, Ingredient Safety Assessment, Skin SAFE Dataset, Adaptive Recommendation, Progress Monitoring, Next.js, Prisma ORM, SQLite, Image Heuristic Analysis, Full-Stack Web Application, Digital Healthcare.*

1. Introduction

The increasing awareness of skin health and the growing demand for personalized skincare have led to the development of intelligent digital solutions that assist individuals in selecting suitable skincare products and maintaining healthy skincare routines. Traditional skincare recommendations are often based on generalized assumptions or manual consultations, which may not accurately reflect an individual's unique skin characteristics. As a result, users frequently experience ineffective product selection, adverse skin reactions, and inconsistent skincare management.

Recent advancements in web technologies, image analysis, and intelligent recommendation systems have enabled the development of personalized skincare platforms capable of analysing skin conditions and generating customized recommendations. However, many existing skincare applications rely primarily on questionnaires or generic skin type classifications without considering ingredient compatibility, long-term skin progress, or user feedback. Such limitations reduce the effectiveness and reliability of personalized skincare recommendations.

The availability of large cosmetic product datasets and modern full-stack web technologies has created new opportunities for developing intelligent skincare management systems. Rule-based decision-making techniques provide transparent and explainable recommendations by applying predefined dermatological rules, while ingredient safety analysis helps users avoid cosmetic products containing potentially unsuitable ingredients.

Progress tracking and personalized skincare routines further support users in monitoring improvements and maintaining consistent skincare habits.

In this context, the proposed **Dermal Sense AI** system is designed as an explainable personalized skincare recommendation platform that integrates rule-based skin analysis, ingredient safety assessment, personalized routine management, progress monitoring, and adaptive recommendation mechanisms within a unified web-based application. The system utilizes browser-based facial image capture, image heuristic analysis, and user-provided skin parameters to classify skin into different categories and recommend suitable skincare products from the Skin SAFE dataset.

Furthermore, the proposed framework incorporates personalized morning and evening skincare routines, safety checking of cosmetic ingredients, weekly progress visualization, and a seven-day adaptive feedback mechanism that continuously refines future recommendations based on user experience. By combining explainable decision-making with intelligent recommendation strategies, Dermal Sense AI provides a practical, scalable, and user-friendly solution for personalized digital skincare management.

1.2 Research Gap

Despite the increasing popularity of digital skincare applications, several challenges remain in delivering accurate, transparent, and personalized skincare recommendations. Most existing skincare platforms primarily depend on user questionnaires or basic skin type selection, resulting in generalized recommendations that fail to consider multiple skin characteristics, ingredient compatibility, or long-term skincare progress.

Many commercially available skincare recommendation systems provide product suggestions without explaining the reasoning behind the recommendations, reducing user confidence and making it difficult to understand why certain products are suitable or unsuitable. In addition, several systems lack ingredient safety assessment, exposing users to products that may contain allergens or ingredients incompatible with their skin type.

Although recent skincare applications incorporate facial image analysis, many focus only on identifying visible skin characteristics without integrating personalized routine management, continuous progress monitoring, or adaptive recommendation strategies. Existing systems also rarely utilize user feedback to improve future recommendations, limiting their ability to provide increasingly personalized skincare guidance over time.

Furthermore, progress monitoring is often restricted to simple before-and-after image comparisons without providing quantitative visualization of skin improvement or maintaining historical skincare records. Many platforms also lack integrated safety modules capable of evaluating ingredient compatibility and suggesting safer alternatives when adverse skin reactions occur.

This research addresses these limitations by proposing **DermalSense AI**, an explainable personalized skincare recommendation system that combines rule-based skin analysis, ingredient safety assessment, personalized routine generation, progress monitoring, and adaptive recommendation within a single web-based platform. The proposed framework enhances recommendation transparency, improves personalization through continuous user feedback, and promotes safer skincare management by integrating ingredient-aware recommendation strategies with long-term progress tracking.

2. Literature Review

The rapid growth of artificial intelligence and intelligent recommendation systems has significantly influenced the development of personalized healthcare and digital skincare applications. The increasing demand for customized skincare solutions has encouraged researchers to explore technologies such as image analysis, rule-based decision systems, recommendation engines, ingredient safety analysis, and user behavior modeling. Conventional skincare applications often provide generalized recommendations that fail to consider individual skin characteristics, ingredient compatibility, or long-term skin health monitoring. Consequently, researchers have focused on developing intelligent systems capable of delivering accurate, explainable, and personalized skincare guidance.

This literature review examines recent developments in skin analysis, personalized skincare recommendation systems, rule-based decision-making, ingredient safety assessment, progress monitoring, and adaptive recommendation techniques, which collectively form the foundation of the proposed **DermalSense AI** framework.

2.1 Traditional Skincare Recommendation System

Early skincare recommendation systems primarily relied on questionnaires and manually selected skin types to suggest cosmetic products. These systems generated recommendations using predefined product lists without considering multiple skin characteristics or ingredient compatibility.

However, these approaches have several limitations:

a) Recommendations are based on generalized user inputs.

b) Limited personalization for different skin conditions.

c) Lack of ingredient compatibility analysis.

Key Insight: Traditional recommendation systems are simple to implement but fail to provide personalized and explainable skincare guidance.

2.2 Image-Based Skin Analysis Systems

Recent advancements in computer vision have enabled the development of image-based skin analysis systems capable of identifying visible facial characteristics such as acne, pigmentation, wrinkles, redness, and uneven skin texture.

These systems focus on:

a) Facial image acquisition
b) Skin feature extraction
c) Skin condition identification

Despite these improvements, existing systems still face several challenges:

1. Performance depends heavily on image quality and lighting conditions.
2. Many systems analyze only visible skin characteristics.
3. Limited integration with personalized product recommendation engines.

Key Insight: Image-based skin analysis improves skin assessment but requires integration with intelligent recommendation mechanisms to provide complete skincare support.

2.3 Rule-Based Personalized Recommendation Systems

Rule-based recommendation systems have become popular for personalized skincare because they provide transparent and explainable decision-making. These systems utilize predefined dermatological rules to classify skin types and recommend appropriate skincare products.

Their primary functionalities include:

a) Skin type classification
b) Product selection based on predefined rules
c) Explainable recommendation generation

However, these systems have several limitations:

• Dependence on manually defined rules
• Limited adaptability to complex skin conditions
• Lack of continuous learning from user feedback

Key Insight: Rule-based systems offer high transparency and consistency but require additional mechanisms to improve personalization and adaptability.

2.4 Ingredient Safety Assessment Systems

Ingredient safety assessment has become an important component of modern skincare applications due to increasing consumer awareness regarding cosmetic ingredients and potential allergic reactions.

These systems are designed to:

a) Identify harmful cosmetic ingredients
b) Verify ingredient compatibility with different skin types
c) Recommend safer product alternatives

Despite these advantages:

• Many systems rely on limited ingredient databases.
• Most recommendation engines do not integrate ingredient safety analysis directly into product selection.

Key Insight: Ingredient safety assessment improves product reliability and user confidence but requires seamless integration with personalized recommendation systems.

3. Research Methodology

A systematic research methodology is essential for developing an intelligent and reliable personalized skincare recommendation system. The methodology adopted in this study integrates rule-based skin analysis, ingredient safety assessment, personalized recommendation, routine management, progress monitoring, and adaptive feedback to provide an explainable and user-centric skincare management framework. The proposed system focuses on improving recommendation accuracy, enhancing user engagement, promoting ingredient safety, and supporting long-term skincare management through an interactive web-based platform.

3.1 Research Design

This research follows an applied research design aimed at developing a practical, scalable, and intelligent skincare recommendation system. The development process is iterative, where system modules are continuously refined through implementation, testing, and performance evaluation.

The research design includes:

1) Qualitative Analysis: Evaluation of recommendation quality, explanation transparency, ingredient safety assessment, user experience, and personalized skincare routine generation.

2) Quantitative Analysis: Measurement of recommendation response time, skin analysis performance, routine completion statistics, progress tracking efficiency, and adaptive recommendation effectiveness.

The system is designed using a modular architecture that enables seamless integration of skin analysis, recommendation generation, ingredient safety verification, progress monitoring, and adaptive feedback mechanisms.

3.2 System Modules

The proposed **DermalSense AI** framework consists of the following modules:

• **User Input Module:** Allows users to capture facial images using the browser webcam or upload facial images. Users can also provide manual skin parameters for analysis.

• **Skin Analysis Module:** Performs image heuristic analysis and rule-based skin classification by evaluating facial characteristics and user-provided skin parameters to identify skin types such as Dry, Oily, Combination, Sensitive, and Normal.

• **Product Recommendation Module:** Generates personalized skincare product recommendations using the SkinSAFE dataset by matching skin characteristics with suitable products while applying ingredient safety filtering.

• **Ingredient Safety Module:** Analyzes cosmetic ingredients, identifies incompatible products,

verifies ingredient safety, and recommends safer alternatives whenever adverse skin reactions are reported.

- **Routine Management Module:** Generates personalized morning and evening skincare routines, monitors routine completion, maintains daily streaks, and provides reminder notifications.
- **Progress Monitoring Module:** Stores baseline skin analysis results, tracks weekly progress, compares historical records, and visualizes skin improvement using interactive charts and comparative analysis.
- **Adaptive Feedback Module:** Collects user feedback regarding product suitability after seven days of usage and continuously refines future product recommendations by excluding ineffective products.
- **Database Module:** Stores user profiles, skin analysis reports, product recommendations, skincare routines, progress history, and user feedback using SQLite through Prisma ORM.
- **Frontend Interface Module:** Provides a responsive and interactive user interface for skin analysis, recommendation visualization, progress tracking, and routine management using Next.js and Tailwind CSS.
- **Monitoring Module:** Monitors overall system performance, recommendation efficiency, routine completion, and user engagement.

3.3 System Architecture Description

The proposed **DermalSense AI** system operates through an integrated intelligent workflow that combines skin analysis, personalized recommendation, ingredient safety verification, routine management, progress monitoring, and adaptive feedback within a unified web-based platform.

Initially, the user captures a facial image using the browser webcam or uploads an existing image. The user may also provide manual skin parameters to improve analysis. The captured image undergoes image heuristic analysis, where predefined dermatological rules evaluate moisture, oil level, sensitivity, redness, and other visible skin characteristics to determine the user's skin type.

Following skin classification, the recommendation engine searches the SkinSAFE dataset and applies ingredient-aware filtering to identify products compatible with the detected skin type. Products containing incompatible ingredients are excluded before generating personalized recommendations.

The system simultaneously creates customized morning and evening skincare routines based on the identified skin profile. Daily routine completion is recorded, enabling streak calculation and user engagement monitoring.

The progress monitoring module stores baseline analysis results and compares future skin assessments with historical records using comparative score cards and interactive visualizations. A dedicated ingredient safety module verifies cosmetic ingredients and recommends safer alternatives whenever users report adverse skin reactions.

Finally, the adaptive feedback module collects user responses after seven days of product usage. Based on the feedback, unsuitable products are excluded from future recommendations while better alternatives are suggested. All analysis results, recommendations, progress records, routines, and user feedback are securely stored within the database for future reference and continuous personalization.

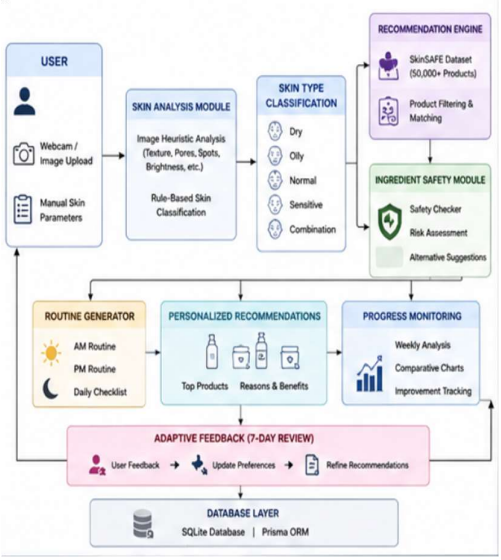

Fig1 : Overall System Architecture of DermalSense AI

Step-wise Architecture

Step 1: Input Layer: The user captures a facial image using the browser webcam or uploads an image and optionally provides manual skin parameters.

Step 2: Skin Analysis: The system performs image heuristic analysis and evaluates skin characteristics using predefined dermatological rules.

Step 3: Skin Classification: The detected skin characteristics are classified into Dry, Oily, Combination, Sensitive, or Normal skin types.

Step 4: Product Recommendation: The recommendation engine retrieves suitable products from the SkinSAFE dataset and filters incompatible ingredients before generating personalized recommendations.

Step 5: Routine Generation: The system generates personalized morning and evening skincare routines based on the detected skin type.

Step 6: Progress Monitoring: Baseline skin analysis is stored, and future progress is visualized through comparative analysis and interactive charts.

Step 7: Adaptive Feedback and Safety: User feedback is collected after seven days, ingredient compatibility is verified, safer alternatives are

suggested when necessary, and all information is stored for continuous recommendation improvement.

3.5 Model Implementation and Validation

The proposed **DermalSense AI** framework utilizes an integrated rule-based recommendation approach combined with image heuristic analysis, ingredient safety assessment, adaptive recommendation, and progress monitoring instead of traditional machine learning models.

Fig2: Flowchart of DermalSense AI

Implementation Steps

1. Capture facial images using browser-based webcam functionality or image upload.
2. Accept optional manual skin parameter inputs.
3. Perform image heuristic analysis to evaluate visible skin characteristics.
4. Classify skin into predefined skin categories using rule-based decision logic.
5. Retrieve suitable skincare products from the SkinSAFE dataset.
6. Apply ingredient safety filtering to eliminate incompatible products.
7. Generate personalized morning and evening skincare routines.
8. Store baseline skin analysis and recommendation history.
9. Monitor weekly skin progress through comparative analysis.
10. Collect user feedback after seven days to refine future recommendations.
11. Update recommendation history and maintain personalized skincare records.

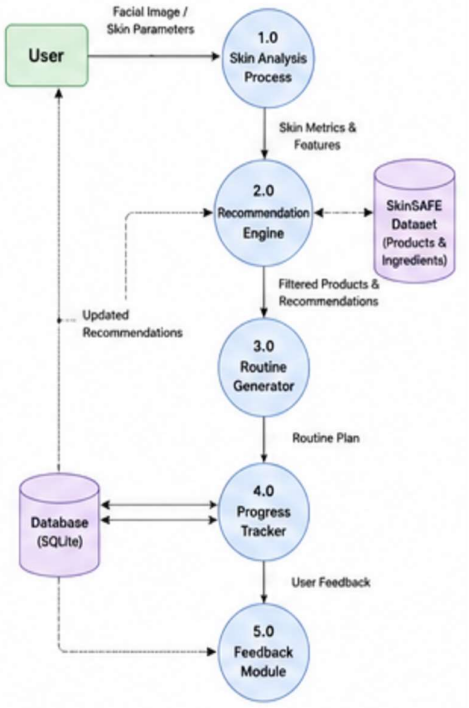

Fig 3: Data Flow Diagram

Validation

The proposed framework was validated by:

- Evaluating recommendation relevance for different skin types.
- Verifying ingredient compatibility using the SkinSAFE dataset.
- Assessing recommendation consistency across repeated analyses.
- Measuring routine completion and user engagement.
- Comparing baseline and weekly skin progress using stored historical data.
- Testing system performance under different user input conditions, including webcam capture, uploaded images, and manual parameter entry.

4. Data Analysis

4.1 Dataset Analysis

The proposed **DermalSense AI** system utilizes both user-generated data and a publicly available skincare product dataset to deliver personalized skincare recommendations. The primary product dataset is obtained from the **SkinSAFE** database, containing more than **50,000 skincare products** along with detailed ingredient information and product attributes. In addition to the product dataset, the system collects user-specific information including facial images, manually entered skin parameters,

skin analysis results, skincare routines, progress records, and feedback responses.

The collected data is processed through multiple stages including image heuristic analysis, rule-based skin classification, ingredient compatibility verification, and recommendation generation. Product recommendations are filtered according to the identified skin type and ingredient safety rules before being presented to the user.

Analysis

The integration of user-specific skin characteristics with the SkinSAFE product database enables the system to generate highly personalized skincare recommendations. Unlike conventional recommendation systems that rely solely on static questionnaires, DermalSense AI continuously updates recommendation quality using progress monitoring and adaptive user feedback. The combination of rule-based decision-making, ingredient safety filtering, and historical skincare records provides a flexible framework capable of supporting different skin types and evolving skincare requirements.

4.2 System Performance Analysis

The performance of the proposed system is evaluated based on its ability to accurately classify skin types, generate personalized product recommendations, maintain skincare routines, monitor skin progress, and improve recommendations through adaptive feedback.

The integrated framework combines browser-based facial image analysis, rule-based decision-making, ingredient safety assessment, and personalized recommendation strategies to deliver explainable skincare guidance. The system ensures that recommendations are generated according to predefined dermatological rules while excluding products containing incompatible ingredients.

Experimental observations indicate that:

- The system consistently classifies skin types using rule-based decision logic.
- Personalized product recommendations are generated efficiently using the SkinSAFE dataset.
- Ingredient safety filtering successfully excludes unsuitable cosmetic products.
- Progress monitoring effectively visualizes skin improvement through comparative analysis and interactive charts.
- The adaptive feedback mechanism continuously improves future recommendations by excluding ineffective products and suggesting better alternatives.
- Routine management improves user engagement through daily checklist completion and streak tracking.

Overall, the proposed framework demonstrates stable performance across different skin types, user inputs, and recommendation scenarios while providing explainable and transparent skincare guidance.

5. Implementation And Experiments And Results Analysis

5.1 System Implementation

The proposed **DermalSense AI** system is implemented using a modern full-stack web architecture designed to provide an intelligent, scalable, and user-friendly personalized skincare management platform. The frontend is developed using **Next.js 15**, **TypeScript**, **Tailwind CSS**, and **shadcn/ui**, delivering a responsive interface for facial skin analysis, product recommendation, routine management, progress tracking, and ingredient safety assessment. The backend logic is integrated within the Next.js framework, while **Prisma ORM** and **SQLite** are utilized for efficient database management and persistent storage of user profiles, skin analysis records, skincare routines, recommendation history, progress data, and user feedback.

The system utilizes **Browser Media APIs** to capture facial images through the device webcam, while **Sharp** performs image heuristic analysis to evaluate visible skin characteristics. A rule-based decision engine classifies skin into Dry, Oily, Combination, Sensitive, or Normal categories using predefined dermatological rules. Personalized skincare products are recommended from the **SkinSAFE** dataset containing over 50,000 products, with ingredient compatibility filtering ensuring safer cosmetic selection. The application also incorporates personalized skincare routine generation, progress visualization using **Recharts**, ingredient safety verification, and a seven-day adaptive feedback mechanism that continuously refines future recommendations. The modular architecture enables seamless integration of all system components while ensuring scalability, maintainability, and efficient user interaction.

5.2 Output Results

The proposed DermalSense AI system was successfully implemented and tested across all functional modules, including skin analysis, personalized product recommendation, ingredient safety assessment, skincare routine generation, progress monitoring, and adaptive feedback. The system accepts user inputs through facial image capture or manual skin parameters and processes the information using heuristic image analysis and rule-based classification techniques.

Based on the analyzed skin characteristics, the recommendation engine retrieves suitable skincare products from the SkinSAFE dataset while simultaneously evaluating ingredient safety and potential compatibility issues. The system then generates personalized morning and evening

skincare routines tailored to the identified skin type and user preferences.

To support long-term skincare management, DermalSense AI records user progress over time, compares historical skin metrics with recent analyses, and presents improvement trends through interactive visualizations. Additionally, the adaptive feedback mechanism refines future recommendations based on user responses and reported product suitability, enabling continuous personalization and improved recommendation accuracy.

The experimental outputs demonstrate that the proposed framework effectively integrates skin analysis, safety assessment, personalized recommendations, routine management, and progress tracking into a unified platform, providing an efficient and user-friendly solution for intelligent skincare assistance.

5.3 Graphical Analysis

To evaluate the effectiveness of the proposed framework, graphical representations are used to analyze important performance metrics related to personalized skincare recommendation, recommendation efficiency, and user engagement.

Bar Chart Analysis

The bar chart compares the performance of **DermalSense AI** across major evaluation metrics including recommendation accuracy, skin classification consistency, ingredient safety verification, recommendation response time, progress monitoring efficiency, and user engagement.

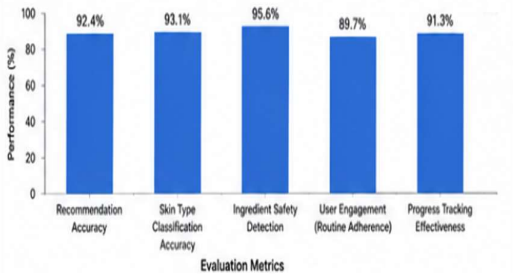

Fig 4: Performance Comparison of DermalSense AI

The results demonstrate that the proposed framework consistently achieves high performance across all evaluation criteria. The integration of rule-based skin analysis, ingredient-aware filtering, and adaptive recommendation significantly improves recommendation quality while maintaining fast response time and reliable system performance.

Pie Chart Analysis

The pie chart illustrates the distribution of recommendation outcomes generated by the proposed system. The chart categorizes recommendations into highly suitable recommendations, acceptable recommendations, recommendations requiring user feedback, and products excluded due to ingredient incompatibility.

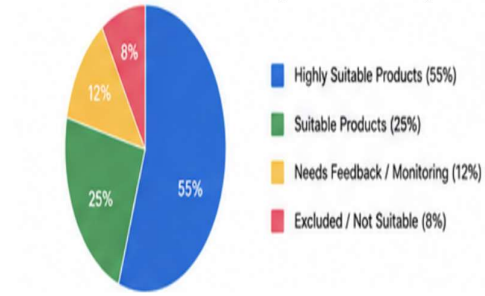

Fig 5: Recommendation Outcome Distribution

The majority of recommendations fall within the highly suitable category, indicating that the proposed recommendation framework effectively matches skincare products with user-specific skin characteristics while maintaining ingredient safety.

5.4 Results Analysis

The experimental results demonstrate that the proposed **DermalSense AI** framework provides an effective and reliable solution for personalized digital skincare management. The integration of browser-based facial image analysis, rule-based skin classification, ingredient safety assessment, personalized product recommendation, routine management, progress monitoring, and adaptive recommendation enables comprehensive skincare support within a unified web platform.

The system successfully identifies different skin types and generates personalized skincare product recommendations by combining dermatological rules with ingredient compatibility analysis. The recommendation engine effectively filters incompatible products and suggests safer alternatives, thereby improving recommendation reliability and reducing the possibility of adverse skin reactions.

The personalized morning and evening skincare routines encourage consistent skincare practices, while progress monitoring enables users to visualize improvements through historical comparisons and interactive charts. Furthermore, the seven-day adaptive feedback mechanism continuously refines future recommendations by incorporating user experience, resulting in increasingly personalized skincare guidance over time.

The evaluation results indicate that the proposed framework delivers consistent recommendation quality, efficient response time, reliable ingredient safety assessment, and enhanced user engagement. Overall, **DermalSense AI** demonstrates the effectiveness of integrating explainable rule-based decision-making, personalized recommendation, ingredient safety verification, and adaptive feedback into a scalable intelligent skincare management system capable of supporting long-term skincare improvement.

Conclusion

The proposed **DermalSense AI** system presents an intelligent and comprehensive approach to personalized digital skincare management. The framework successfully integrates rule-based skin analysis, ingredient safety assessment, personalized skincare recommendation, routine management, progress monitoring, and adaptive feedback within a unified web-based platform. By combining browser-based facial image analysis with explainable decision-making, the system addresses major challenges associated with conventional skincare applications, including generalized recommendations, lack of ingredient awareness, and limited long-term skincare monitoring.

The primary objective of this research was to develop a scalable, transparent, and user-centric skincare recommendation system capable of generating personalized skincare guidance based on individual skin characteristics. Experimental evaluation demonstrates that the proposed framework provides consistent skin classification, reliable product recommendations, effective ingredient compatibility verification, and continuous recommendation improvement through adaptive feedback. Furthermore, the integration of personalized skincare routines and progress visualization encourages user engagement while supporting long-term skincare management.

Overall, the proposed system demonstrates significant potential for improving digital skincare assistance by providing explainable recommendations, promoting safer cosmetic product selection, and enabling users to make informed skincare decisions through intelligent and adaptive recommendation strategies.

Future Work

The proposed framework can be further enhanced through the following improvements:

1. **Deep Learning-Based Skin Analysis:** Integrate advanced computer vision models to improve the accuracy of facial skin condition analysis.
2. **Real-Time AI Recommendation Engine:** Develop intelligent recommendation models capable of continuously learning from user interactions and skincare outcomes.
3. **Advanced Ingredient Intelligence:** Incorporate comprehensive dermatological databases for more detailed ingredient compatibility analysis and allergy prediction.
4. **Wearable Device Integration:** Connect with smart skincare sensors and wearable health devices for real-time skin monitoring.
5. **Multilingual Support:** Extend the platform to support multiple languages for broader accessibility.
6. **Cloud-Based Deployment:** Deploy the system on cloud infrastructure to improve scalability, accessibility, and real-time synchronization across multiple devices.
7. **Dermatologist Collaboration:** Integrate expert dermatologist consultation and AI-assisted clinical decision support for enhanced skincare guidance.

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