Ms. Pooja Patil, 2026, 14:1
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

International Journal of Science, Engineering and Technology
An Open Access Journal

SMART COMB: An AI-Powered Smart Hair Comb for Scalp Health and Hair Therapy

[1] Ms. Pooja Patil, [2] Shreya Patil, [3] Khushi Nakhwa, [4] Bhumisha Koli

Abstract- The Smart Hair Comb is a technology-based grooming device created to examine scalp conditions and assist users in choosing suitable treatment methods. It operates by gathering live readings related to scalp temperature and surrounding moisture levels. These measurements help in understanding the present scalp condition and in recommending appropriate corrective care. The device includes a small digital screen that presents readings and suggestions in a clear format, allowing users to easily interpret the results. Its lightweight structure supports routine use and encourages individuals to maintain consistent scalp care habits. The design focuses on simplicity so that it can be used comfortably without technical expertise. This project reflects the practical implementation of sensor-driven systems in personal wellness equipment, promoting better awareness of scalp health over time.

Keywords: AI-based hair care, scalp treatment, therapeutic technologies, modern technology.

I. INTRODUCTION

Proper scalp maintenance plays a key role in maintaining healthy hair and overall self-care. Issues such as dryness, excessive oil accumulation, dandruff, and weak circulation often develop gradually and may not be identified at an early stage [1]. Conventional approaches usually depend on observation and commonly available products, which may not suit every scalp type [4]. Because of this limitation, there is a demand for a more reliable and condition-based solution. Advancements in embedded electronics have enabled the development of compact systems capable of collecting and processing biological parameters instantly. Integrating these advancements into grooming tools allows individuals to make informed decisions without depending entirely on salons or expensive procedures. The Smart Comb developed in this study provides an economical home-based alternative that combines sensing elements, light-based treatment, and user controls. The main aim of this work is to build and validate a device that remains affordable while delivering effective scalp support [5].

II. LITERATURE SURVEY

Earlier hair care solutions mainly relied on cosmetic applications rather than data-driven evaluation. Scientific findings suggest that scalp temperature balance, humidity level, and blood circulation significantly influence hair strength and growth. Disturbances in these factors can result in dryness, excessive oil secretion, irritation, or hair thinning [1]. Recent developments in wearable healthcare devices demonstrate that environmental and skin- related parameters can be measured accurately using compact sensors. Temperature and humidity sensing technologies are widely used for evaluating skin conditions. In addition, controlled light exposure techniques are increasingly studied. Red wavelength exposure is often linked with improved circulation and stimulation of hair roots, whereas blue wavelength exposure is associated with reducing microbial activity and oil imbalance Although certain modern grooming devices are available, many depend on smartphone connectivity and cloud-based processing, limiting independent functionality [3]. Furthermore, high cost and operational complexity reduce their suitability for everyday users. These drawbacks highlight the necessity for a standalone, cost-efficient, and easy-to- handle solution capable of providing immediate feedback.

The Smart Hair Comb proposed in this study integrates measurement, processing, and response mechanisms within a single handheld unit. By concentrating on essential scalp indicators and maintaining operational simplicity, the device is intended to support routine scalp management effectively [3].

III. METHODOLOGY

System Design and Requirements
The smart comb is developed to monitor and evaluate scalp conditions while providing personalized care. The design process began with defining essential requirements, including comfort, portability, real-time monitoring, and user-friendly operation. These requirements guided the selection of suitable hardware and software components to create a compact and functional system. The comb is designed ergonomically to ensure ease of handling and suitability for daily use.

Hardware Components
The comb integrates sensors to measure key scalp parameters such as temperature, humidity, and moisture. These sensors continuously gather data and transmit it to an ESP32 microcontroller, which acts as the central processing unit. The microcontroller manages communication with the sensors, processes the collected data, and controls output devices, including the OLED display and therapy functions.

Data Analysis and Therapy Activation
The collected sensor data is analyzed to identify the scalp condition as dry, oily, or normal. Based on the analysis, the system automatically activates the appropriate therapy mode: red light to stimulate hair growth, blue light to reduce dandruff and inflammation, and vibration to enhance blood circulation. Button controls are provided to allow manual selection of therapy modes, and the OLED display presents real-time feedback on scalp health.

Testing and Implementation
Before final assembly, the circuit is tested on a breadboard to calibrate the sensors and verify correct operation of the system. After successful validation, the components are integrated into the final comb design. The device is powered by a rechargeable battery, ensuring portability and convenience for personal use. This methodology demonstrates how integrating sensors, data processing, and therapy functions in a single device can provide accurate, practical, and user-friendly scalp care.

IV. PROPOSED SYSTEM

The proposed Smart Hair Comb system is designed to monitor scalp conditions and assist users in selecting suitable hair therapy through real-time sensing and controlled actuation. [2]. The methodology focuses on systematic data acquisition, condition analysis, and user-guided therapy execution. The complete working of the system is divided into the following stages.

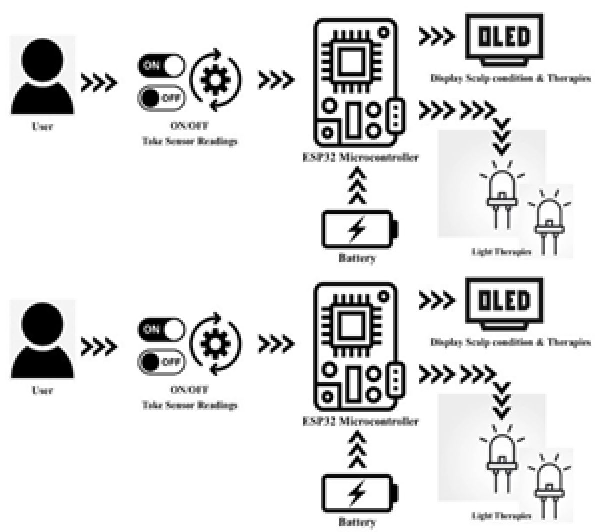


Figure: System Architecture

Data Collection
The system begins by collecting real-time scalp data using an onboard temperature and humidity sensor. These parameters are selected as they directly influence scalp moisture balance and comfort levels. The raw sensor readings are checked for validity and

stability before further processing. Invalid or fluctuating readings are ignored to ensure reliable output. The processed data forms the basis for evaluating the scalp condition.

Sensing

The sensing module continuously monitors the scalp environment when activated by the user. The sensor captures temperature and humidity values and sends them to the microcontroller for analysis. The sensing operation can be manually enabled or disabled using a dedicated button, allowing the user to control when measurements are taken. This approach ensures power efficiency and avoids unnecessary data collection.

Scalp Condition Evaluation

Based on predefined threshold ranges derived from dermatological studies, the system classifies the scalp condition into categories such as dry, normal, or oily. These classifications are determined by comparing the sensed humidity values against standard ranges suitable for scalp health. This step converts raw sensor data into meaningful information that can be easily understood by the user.

Therapy Suggestion

After determining the scalp condition, the system suggests a suitable therapy mode. Red light therapy is recommended for dry or normal scalp conditions to support blood circulation, while blue light therapy is suggested for oily scalp conditions to help regulate excess oil. The system also recommends a therapy duration based on the measured humidity level. All results, including sensor values, scalp condition, therapy type, and suggested duration, are displayed on an onboard OLED screen.

Therapy Activation

Based on the detected scalp condition, the appropriate therapy is selected and activated manually by the user using dedicated control buttons. Red light therapy is applied for dry or normal scalp conditions, while blue light therapy is used for oily scalp conditions. The therapy duration is determined using predefined threshold values. This approach ensures controlled, safe, and user-guided scalp treatment.

Power and Implementation

During development and testing, the system is powered through an external supply. The design supports integration with a portable battery for real-world usage. All components are initially tested on a breadboard to validate functionality before final enclosure fabrication using 3D printing.

V. RESULT ANALYSIS

The Smart Comb prototype was successfully developed on a breadboard, and the functionality of each component was tested and verified. The results of the experiment are presented below.

System Initialization

Upon powering the device, the OLED display showed the startup message "Welcome to Smart Comb", indicating that the system booted correctly and all initializations were successful.

Figure 2: OLED Display Showing "Welcome to Smart Comb"

Sensor Reading Display

Next, the comb's scalp sensor detected real-time parameters, which were displayed on the OLED screen. This confirmed that the sensing module was functioning correctly and transmitting accurate data to the microcontroller.

Figure 3: OLED Display Indicating Humidity, Temperature, Scalp Condition, and Therapy Mode

Scalp Condition Analysis and Therapy Recommendation

Using the measured humidity values, the system analyzes the scalp condition and classifies it as dry, normal, or oily. Based on the identified scalp condition, the system then displays the recommended therapy type along with the suggested treatment duration on the OLED screen. Blue light therapy for oily scalp condition, while red light therapy for dry or normal scalp condition.

Figure 4: OLED Display Showing Scalp Condition and Therapy Recommendation with Duration

D. Manual Therapy Control

The push buttons are used to manually activate the recommended therapy. Pressing the button successfully triggered the corresponding therapy mode, confirming proper operation of the user control interface.

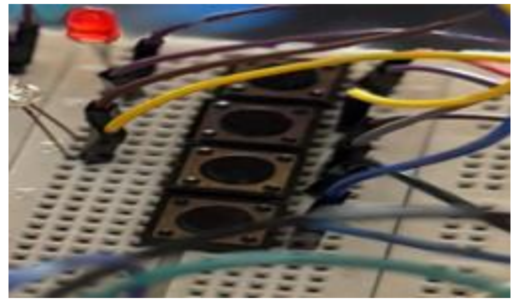


Figure 5: Push Button Interface Used for Therapy Activation

Therapy Activation Using LEDs

After pressing the control button, the respective LED turned ON. The red LED indicated red light therapy, while the blue LED indicated blue light therapy, confirming successful therapy activation.

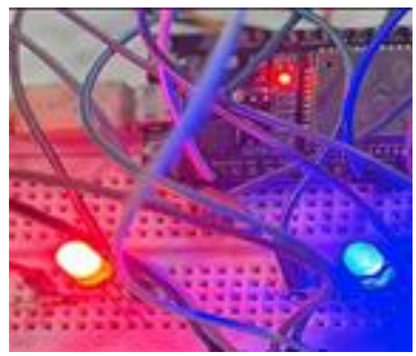


Figure 6: Red and Blue LEDs Showing Therapy Activation

Complete System Operation

All components—including the microcontroller, sensor, OLED display, push buttons, and therapy LEDs—worked together smoothly. The successful operation of the full breadboard setup verified the proper implementation of the Smart Hair Comb prototype.

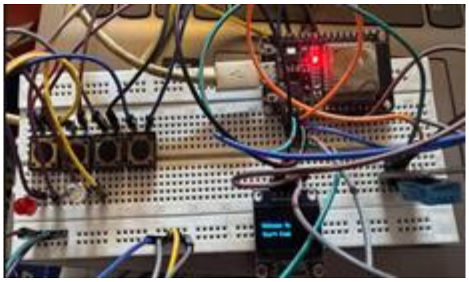
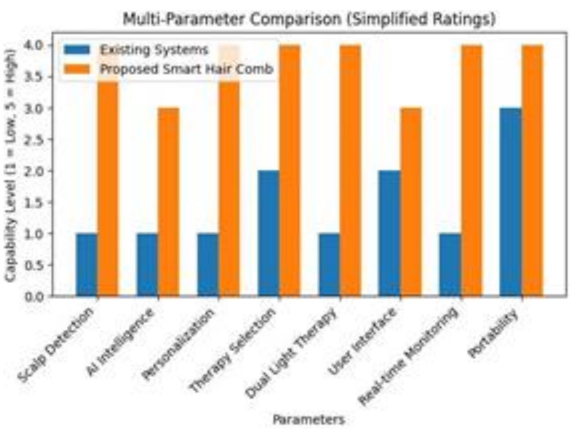


Figure 7: Complete Hardware Setup of the Smart Hair Comb Prototype

VI. SYSTEM COMPARISON



The comparison between existing hair care systems and the proposed Smart Hair Comb is carried out to evaluate their functional capabilities across multiple parameters. The analysis highlights how the proposed system improves scalp monitoring, therapy selection, and user interaction when compared to conventional approaches.

Scalp Analysis
Existing systems do not perform scalp condition analysis, whereas the proposed system uses embedded sensors to detect scalp conditions such as oily, dandruff-prone, or normal scalp.

Intelligence
Existing systems operate without intelligent processing and rely on manual operation, while the proposed system applies logic-based analysis for decision making

Personalization
Existing systems provide uniform treatment to all users, whereas the proposed system offers personalized therapy based on the detected scalp condition.

Therapy Selection
In existing systems, therapy selection is performed manually, while in the proposed system, suitable therapy is automatically suggested based on sensor data.

Light Therapy
Existing systems generally support single-function or separate therapy devices, whereas the proposed system integrates both red and blue light therapy within a single unit.

User Interface
Existing systems lack direct user feedback mechanisms, while the proposed system provides real-time feedback through an OLED display.

Monitoring
Existing systems do not support continuous monitoring, whereas the proposed system enables real-time monitoring of scalp conditions during use.

Portability
Existing systems are often bulky or clinic-based, while the proposed system is compact, portable, and suitable for home use.

Overall Performance
Existing systems demonstrate lower capability levels across the evaluated parameters, whereas the proposed system shows improved performance in all aspects, as reflected in the comparison graph.

VII. SCOPE OF RESEARCH

The scope of this research is focused on the design and development of an IoT-based Smart Hair Comb for monitoring scalp conditions and providing suitable hair therapy suggestions. The proposed system incorporates embedded sensors to measure scalp parameters such as temperature and humidity in real time during usage. The collected sensor data is processed to evaluate the scalp condition and to identify issues such as dryness, excess moisture, or abnormal temperature variations. Based on the evaluated condition, the system suggests appropriate therapy modes, including red light therapy for scalp stimulation and improved circulation, and blue light therapy for maintaining scalp hygiene. The scope of the study also includes real-time display of sensor readings on an OLED screen and emphasizes the development of a compact, low-cost, and user-friendly device intended for personal hair and scalp care applications.

VIII. CONCLUSION

The AI-powered Smart Hair Comb presented in this research offers an advanced approach to personal hair and scalp care by integrating IoT-based sensing and intelligent decision support. The system combines multiple features such as red and blue light therapy, vibration-based scalp stimulation for improved blood circulation, real-time scalp condition sensing, and an embedded display interface for user feedback. By continuously monitoring parameters such as scalp temperature and humidity, the device enables accurate assessment of scalp conditions and provides suitable therapy recommendations based on the observed data. The real-time monitoring capability enhances user awareness of scalp health and encourages informed grooming practices. The compact and user-friendly design makes the system suitable for daily use, while the use of cost-effective components ensures practical implementation. This work highlights the effective application of AI and IoT technologies in developing smart wellness devices and demonstrates their potential to support preventive care and personalized treatment in the domain of hair and scalp health.

IX. FUTURE SCOPE

In the future, additional sensors can be integrated into the Smart Hair Comb to measure parameters such as scalp oil level and dryness. This improvement will help in understanding scalp conditions more accurately and in providing better therapy guidance. The system can be further enhanced to store previous scalp readings. This will help users track changes in their scalp condition over time and follow improved hair care routines. Additionally, the Smart Hair Comb can be upgraded to support multiple user profiles. This feature would allow personalized therapy suggestions based on factors such as age, hair type, and usage patterns, making scalp care more effective for different users.

X. DISCUSSION

The implementation of the proposed Smart Hair Comb demonstrates clear improvements over conventional hair care systems. Real-time measurement of scalp parameters such as temperature and humidity enabled effective identification of scalp conditions and supported appropriate therapy suggestions without manual intervention. The integration of red and blue light therapy within a single device enhanced treatment flexibility when compared to existing systems that rely on separate or limited therapy methods. The OLED display improved user interaction by providing immediate feedback on sensed values and selected therapy modes. In addition, vibration-based stimulation supported improved blood circulation, contributing to better scalp care outcomes. The compact and portable design allows the system to be used comfortably in a home environment. Overall, the comparative evaluation shows that the proposed system achieves higher performance across key parameters, highlighting its practicality and effectiveness for personal scalp care applications.

ACKNOWLEDGEMENT

It is a privilege for our team to have worked under the guidance of Pooja Patil ma'am during this project. We have greatly benefited from her valuable advice and constant support. We sincerely express our gratitude for her encouragement, patience, and assistance throughout the completion of this work. Her suggestions have greatly enhanced the quality of our project.

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Author's Details

1. Assistant Proffesor, Computer Engineering, Pillai HOC College Of Engineering and Technology (Autonomous), Ms. Pooja Patil, Maharashtra, India, poojapatil@mes.ac.in
2. Student, Computer Engineering, Pillai HOC College Of Engineering and Technology (Autonomous), Ms. Shreya Patil, Maharashtra, India, patilshreya1518@gmail.com
3. Student, Computer Engineering, Pillai HOC College Of Engineering and Technology (Autonomous), Ms. Khushi Nakhwa, Maharashtra, India, khushinakhwa@gmail.com
4. Student, Computer Engineering, Pillai HOC College Of Engineering and Technology (Autonomous), Ms. Bhumisha Koli, Maharashtra, India, bhumishakoli98@gmail.com