



Project Proposal

The Role of Artificial Intelligence in Curly Hair Analysis

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1. Project Overview

Curly hair is one of the hair types that face challenges in care routine and choosing appropriate products due to the variety of its textures (it varies from 2 to 4 with subcategories from a to c). Although there are some classification systems that help to identify curl patterns and needs, such as Andre Walker System, the Form Inclination Arrangement (FIA Typing) and LOIS Systems, but they do not provide an accurate analysis of each hair type. Besides, many companies produce their products without any specific analysis or understanding of hair characteristics, which leads to the uselessness of their products for some users.

Recently, the world has witnessed significant developments in the field of artificial intelligence (AI), and we see its presence in the previous papers. However, curly hair remains a challenge, due to the wide variety of textures and it requires specific routines and products.

Despite this, most currently available intelligent systems lack sufficient analysis for this hair type. Most databases that used to train algorithms contain images of people with straight or wavy hair, which make curly hair analysis results inaccurate or not specifically designed for the person. Given the importance of this topic, this project aims to explore the role of AI in analyzing curly hair and customizing appropriate products according to the Curly Girl Method (CGM).

2. Project Goal

This project aims to solve the problem of accuracy of curly hair analysis and product recommendation using AI. The project objectives are built around the primary objective, and each objective is structured in such a way as to improve real-world hair analysis accuracy.

1. To evaluate challenges in analyzing curly hair texture and characteristics.
2. To study challenges accompanies using AI technology in cosmetics and hair care routine specially.
3. To propose a model built with AI capable of analyzing curly hair, determining hair condition (protein - moisture balance, frizz, etc) and customizing appropriate products according to the Curly Girl Method (CGM)

3. Approach

To achieve the objectives of this research, a structured AI-based approach will be followed, combining image processing, deep learning, and computer vision techniques. The proposed methodology consists of four main stages: data collection, data processing, model selection, and testing and evaluation.

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3.1 Data Collection

The primary data used in this project will consist of curly hair images. These images may be collected from:

- available public datasets related to hair analysis.
- available public curly-hair product dataset containing product names, ingredient lists
- CGM-approved and non-approved labels based on Curly Girl Method guidelines.
- user-submitted images (if applicable), ensuring privacy and ethical considerations.

3.2 Data Processing

Basic preprocessing will include handling missing values, outlier detection, and feature normalization:

- Image preprocessing such as resizing images, and noise reduction.
- Hair segmentation to isolate hair from the background to focus the analysis only on hair features.
- Feature selection such as curl patterns, frizz indicators, and density.
- Data cleaning for products by standardizing ingredient names and removing duplicate and incomplete records.

3.3 Model and Method Selection

The proposed system relies on deep learning models, specially Convolutional Neural Networks (CNNs) for analyzing curly hair images.

The trained CNN models will be used to classify curl patterns ,assess hair condition such as frizz, and estimate protein–moisture balance. And a rule based and AI assisted matching approach will be used for product recommendation.

3.4 Testing and Evaluation

To evaluate the effectiveness of the proposed system, several performance metrics will be used:

- Accuracy of hair type and condition classification.

- Precision and recall for detecting hair features such as frizz and curl patterns.
- Recommendation relevance, measured by how well the suggested products match the detected hair needs.

4. Project Steps and Timeline

The following timeline outlines the structured phases of the project, strategically distributed over a 10-week period. Each phase has been carefully designed to align with the project's objectives while ensuring feasibility within the available timeframe. The timeline maintains a balance between technical development, analytical rigor, and regulatory integration to deliver a practical and research-driven Curly Hair analysis solution.

Week	Phase	Description
1	Data Collection & initial setup	• Collect curly hair images from public datasets. • Collect CGM product data including ingredient lists. • Set up development environment (Python, Jupyter, OpenCV, TensorFlow/PyTorch) • Perform initial data quality assessment.
2	Data Cleaning & Preprocessing	• Clean and filter hair images, resize and normalize images. • Standardize product ingredients and label products as CGM-approved or CGM-non-approved based on Curly Girl Method guidelines. Document preprocessing steps. • Concurrent literature review and theoretical chapter writing.
3	Exploratory Analysis & Feature Preparation	• Analyze characteristics of curly hair such as curl patterns, density, and frizz indicators. • Concurrent literature review and theoretical chapter writing.
4	Hair Segmentation & Model Implementation	• Hair Segmentation & Model Implementation • Isolate hair regions from images. • Develop CNN-based models to analyze curly hair texture and structure. • Perform initial model training. • Document model architecture. • Concurrent literature review and theoretical chapter writing.
5	Model Optimization & Fine-Tuning	• Optimize CNN models. • Improve classification accuracy. • Document optimal configurations. • Concurrent literature review and theoretical chapter writing.

6	Hair Condition Classification	• Classify hair by its condition indicators such as frizz level, dryness, and protein–moisture balance based on extracted features. • Validate model consistency across different hair types and textures.
7	Product Recommendation System Development	• Implement the recommendation logic that maps analyzed hair conditions to suitable CGM-approved products.
8	Comprehensive Testing & Evaluation	• Test the full system on unseen data and evaluate performance using Accuracy, Precision, and Recall.
9	System Refinement & Final Adjustments	• Analyze evaluation results, refine the models and recommendation logic, and address identified limitations. • Finalize system workflow and prepare complete methodology documentation.
10	Final Documentation & Presentation	• Prepare a full report with methodology, results, regulatory alignment, and lessons learned. • Develop slides or materials for final presentation

5. Expected Results

This project is expected to produce several key outcomes that contribute both academically and practically to the field of artificial intelligence based hair analysis and personalized curly hair care. The anticipated results include:

- Improve Analysis Accuracy For Curly Hair.
- Improve Assessment of Hair Conditions such as Protein-Moisture Balance.
- Customize product recommendations based on CGM.
- Academic Contribution to the Role of Artificial Intelligence in Curly Hair Analysis.

6. Resources Needed

To successfully complete this project, the following resources will be essential across different stages of development, training, and evaluation:

Tools and Software

- Python Programming Language – for model development, data preprocessing, and evaluation.
- Jupyter Notebook – for interactive code execution and experimentation.

- TensorFlow or PyTorch for CNN implementation, OpenCV – key Python libraries for Deep Learning and Computer Vision Libraries
- NumPy and Pandas – key Python libraries for data handling
- Google Colab / Local IDE – for model development and prototyping.

Dataset

Curly Hair Image Dataset: a collection of curly hair images representing different curl patterns, textures, frizz levels, and hair densities, gathered from public datasets.

Curly Hair Product Dataset: a structured dataset containing product names, ingredient lists, and labels indicating whether products are CGM-approved or not according to Curly Girl Method guidelines.

Computing Resources

- Personal Laptop – for initial training and testing.
- Optional Access to Cloud Services (e.g., Google Colab) – for training models or handling larger datasets

Limitations and Risks

Data Availability and Quality:

Collecting suitable data for this project is not easy. Since finding a large number of curly hair images that are clearly labeled takes time, and many available images differ in lighting or hairstyle.

Challenges in Assessing Hair Condition

Some hair conditions cannot be judged accurately from images only. For example, frizz level or protein–moisture balance often depends on touch or personal experience, not just appearance.

Variant of types and textures:

Curly hair also differs greatly from one person to another. If certain curl types or textures are missing or limited in the dataset, the model may work better for some cases than others.

Image and Environmental Differences:

Image background, camera quality, lighting, and previously used hair products can change how the hair looks in photos. These factors may lead to lower classification accuracy.

Time Constraints:

The 10-week project timeline poses challenges for extensive experimentation and validation.

Risk Mitigation Strategies

To reduce the impact of limited data, publicly available curly hair image datasets will be used alongside any collected images. This helps increase data diversity and improves the representation of different curl patterns and hair textures.

In addition, results and recommendations will be reviewed iteratively by comparing them with established curly hair care guidelines. This step helps to ensure that the outputs are reasonable, consistent, and aligned with known curly hair care practices.

Documentation Tools:

- Google Docs– for report writing and structuring project documentation.
- Google Slides – for preparing the final presentation or defense.

7. Literature Review

The following studies and articles represent the foundational literature and prior research that inform the development of this project.

These references provide theoretical background, methodological guidance, and benchmarking insights for curly hair analysis using AI techniques:

#	Title	Name of Researchers	Year	Summary	Methodology	Limitations
1	Towards creation of a curl pattern recognition system	Hill Kymberlee, Abimbola Adesola, Dangal Prajjwhal, Washington Gloria, III Burge Legand	2018	They successfully developed a prototype for hair curl pattern classification using AI techniques and used well-known classifiers systems (Andre Walker, LOIS, FIA) and were also able to analyze images and extract features associated with hair pattern with good accuracy.	They collected images of several curly hair types and used OpenCV to convert the images to grayscale and then binary. They built a CNN to analyze the images and then classified the results according to well-known classification systems.	The database size was limited.And there was no actual user testing.
2	KEBOT: An Artificial Intelligence Based Comprehensive Analysis System for FUE Based Hair Transplantation	Mohammad Ikram, Imran Sarwar Bajwa, Nazeeruddin Mohammad, Faisal Baig	2021	A comprehensive system called KEBOT, based on artificial intelligence techniques, was developed to analyze and process hair transplant cases. The model contributed to improving diagnostic accuracy and customizing treatment plans.	Collecting and analyzing scalp images. Using convolutional neural networks (CNNs) to detect suitable areas for transplantation.	There is insufficient information about user interaction or actual user experience. The system does not include post-transplant recommendations or analysis of hair characteristics such as softness or curl.

3	Neural Strands Learning Hair Geometry and Appearance from Multi-view Images	Radu Alexandru Rosu, Shunsuke Saito , Ziyang Wang, Chenglei Wu, Sven Behnke, and Giljoo Nam	2022	The model learns from images taken from multiple angles, reconstructing a 3D representation of hair that closely resembles the real thing.	Combine data from different angles to create a complete representation of hair strands. Use custom functions to adjust appearance, curl, and bend.	It requires multiple angles of the same person, limiting its practical application in everyday life. It does not provide accurate hair type classification.
4	Artificial Intelligence in hair research: A proof-of-concept study on evaluating hair assembly features	Gabriela Daniels, Slobodanka Tamburic, Sergio Benini, Jane Randall, Tracey Sanderson, Mattia Savardi	2021	The results demonstrated the AI's ability to distinguish between different types of assembly and morphological characteristics, and the algorithms proved effective in visually classifying hair patterns and characteristics without human intervention.	Collecting hair samples from volunteers.	The study did not rely on a large or diverse dataset, but was limited to the samples collected. The system also does not provide product recommendations or direct interaction with the end user.
5	Reimagining Hair Science: A New Approach to Classify Curly Hair Phenotypes via New Quantitative Geometrical & Structural Mechanical Parameters	Michelle E. B. Joly, Audrey R. Miller, Jena A. Shaw, Patricia A. Turner, Crystal M. Morrison, Michelle A. Gaines	2022	A new classification of curly hair has been proposed based on geometric characteristics such as angle, curvature, and length, going beyond the traditional method of relying solely on appearance.	Collect hair samples from volunteers. Develop clear quantitative criteria for classifying hair patterns.	The experiment was conducted on limited samples.

6	DiffLocks: Generating 3D Hair from a Single Image using Diffusion Models	Huiwen Chang, Xiaohui Zeng, Hanbyul Joo, Jingwan Lu, Xiaohui Shen, Jimei Yang	2023	The model produces consistent geometric properties of hair, delivering high-quality results that can be animated and integrated into 3D environments. The model outperforms previous methods in terms of accuracy and realistic appearance.	Using a Diffusion Model. Train the model on data containing 2D images and their corresponding 3D images.	There is no built-in mechanism for automatically identifying hair type or pattern (classification).
7	Scalp Diagnostic System With Label-Free Segmentation and Training-Free Approach	Youngmin Kim, Saejin Kim, Hoyeon Moon, Youngjae Yu, Junhyug Noh	2024	Proposed an AI-driven diagnostic system capable of segmenting hair and scalp without manual labels or extensive training data. Demonstrated efficiency in identifying scalp conditions with reduced data requirements.	Developed label-free segmentation techniques leveraging pseudo-label generation and training-free architectures.	Performance may degrade on rare or complex scalp conditions. Limited generalizability without larger, more diverse datasets.
8	High-throughput phenotyping methods for quantifying hair fiber morphology	Tina Lasisi, Arslan A. Zaidi, Timothy H. Webster, Nicholas B. Stephens, Kendall Rutch, Nina G. Jablonski, Mark D. Shriver	2021	Introduced scalable, quantitative methods to analyze hair fiber morphology including curl, diameter, and cross-sectional shape. Enabled large-scale phenotypic studies and deeper understanding of genetic and environmental influences on hair traits.	Developed imaging-based and computational pipelines for hair fiber analysis. High-throughput quantification included geometric and structural measurements of hair fibers.	May miss microstructural biochemical properties. Focuses more on morphological features than biochemical or health-related ones.

9	Deep Hair Phenomics: Implications in Endocrinology, Development, and Aging	Jasson Makkar, Jorge Flores, Mason Matich, Tommy T. Duong, Sean M. Thompson, Yiqing Du, Isabelle Busch, Quan M. Phan, Qing Wang, Kristen Delevich, Liam Broughton-Neiswanger, Iwona M. Driskell, and Ryan R. Driskell.	2025	Hair phenomics provides insights into developmental and endocrine changes across lifespan. Deep learning models capture correlations between hair morphology and hormonal/aging markers. Highlights hair as a non-invasive biomarker for systemic health.	Integrated high-throughput hair phenotyping, endocrinological assays, and AI-driven pattern recognition. Applied computational models to link hair fiber morphology with hormonal and age-related variables.	Requires large-scale datasets combining medical and phenotypic information.
10	Hairmony: Fairness-aware hairstyle classification	Meishvili, G., Clemoes, J., Hewitt, C., Hosenie, Z., Xiao, X., De La Gorce, M., Takacs, T., Baltrusaitis, T., Criminisi, A., McRae, C., Jablonski, N., Wilczkowiak, M.	2024	The model achieved high accuracy and fairness across diverse hairstyles, especially frizzy, curly, and gathered hair types. It outperformed traditional parametric approaches by using a taxonomy-based classification that reduces bias and improves generalization.	Introduced a new hairstyle taxonomy with 74 attributes; used synthetic hairstyle dataset and FairFace real dataset; trained CNN (DINOv2) with attribute and style prediction heads; evaluated	Some failure cases in detecting short, frizzy, and medium-length gathered hair due to lack of visual cues at the back of the head.

					fairness and accuracy across demographic groups.	
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7.1 Overview of Existing Research

By reviewing previous papers, it is clear that the field of artificial intelligence use in hair analysis is still under development and most previous studies have focused on specific aspects, such as geometric classification, 3D reconstruction, or studying its physical properties.

7.2 Key Research Findings

- development from Manual Classification to Artificial Intelligence:**
 Most of papers demonstrate the evolution of hair problems to interpret its properties, whether for classification, generating its 3D shape, or understanding the geometric structure, from relying on human visual analysis (LOIS System and FIA System) to using AI and deep learning algorithms (such as diffusion models, and neural networks). This development illustrates how studies began with traditional methods before adopting modern techniques to improve accuracy and specificity.
- Reliance on images as the primary source of analysis:**
 All studies relied on images (either single images or multi-angle images) as a starting point to extract information about hair pattern, this emphasizes the importance of the image as a primary input for analysis.
- Variety of technical approaches to achieve the same goal:**
 Tools varied between diffusion models, convolutional networks (CNNs), classification algorithms, and manual techniques, although the overall goal remained within the scope of understanding the hair types.
- Limited practical usability of some models:**
 Some models require multi-angle images or industrial data, making them difficult to implement for everyday users, especially in personal applications.

7.3 Critical Research Gap:

Even with this progress in technology, clear gaps remain. The main gaps are the lack of a comprehensive approach that integrates curly hair analysis, accurately identifying its pattern, and providing personalized recommendations. Furthermore, most previous models were not built on everyday user data such as

mobile phone images, which limits their practical application. Thus, I can say that these studies serve as the foundation building blocks for developing an AI model that accurately analyzes curly hair based on images, classifies it, and provides personalized care recommendations.

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