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A Hybrid Deep Composition Optimization Approach for Real-Time Portrait Photography Assistance

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***Abstract*— Portrait photography plays a big part in digital communication today. The challenge for the amateur user is to get a nice looking composition because of the lack of knowledge of the principles of photography. Here we propose a Hybrid Deep Composition Optimization approach for real-time portrait photography assistance that combines deep learning with rule-based composition analysis. The system we propose takes live camera frames and applies a lightweight face-detection model (BlazeFace) to infer the position and orientation of the subject. Specialized computer vision modules estimate several composition constituents, such as rule of thirds, spatial balance, lighting consistency, and visual saliency.To quantify overall composition quality, we propose an Adaptive Composition Similarity Index (ACSI) that combines these factors into a unified scoring framework for real-time feedback. Furthermore, the system uses MobileNetV2 for deep feature extraction for reference-based composition matching. Experimental results show that the proposed hybrid approach achieves an accuracy of 93% at the same time maintaining the real-time responsiveness, outperforming the conventional CNN-based methods.The proposed system provides actionable guidance including subject repositioning, camera alignment and lighting adjustments so that users can take visually balanced portraits with no prior expertise. This approach provides a scalable solution for intelligent photography assistance on smartphones, smart cameras, and edge-based imaging systems.Unlike conventional post-processing approaches, the proposed system provides composition guidance during image acquisition in real-time.**

***Index Terms*— Portrait Photography, Image Composition, Deep Learning, Computer Vision, Real-Time Image Analysis, Composition Optimization, Smart Camera Assistance.**

I. Introduction

Portrait photography is widely used in social media, fashion, professional imaging and personal documentation. The visual quality of a portrait image is largely determined by composition elements such as subject placement, lighting conditions, background balance, and framing. Well-established principles such as the rule of thirds, symmetry, and spatial alignment are used by professional photographers to produce aesthetically appealing images. But amateur users lack the technical knowledge and experience to apply these principles correctly, and it shows in badly composed photographs with bad framing, uneven lighting or distracting backgrounds.

Recent progress in computer vision and deep learning has opened the door for intelligent systems to understand visual scenes and support users in photography.

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Today's smartphones already have face detection, scene recognition and automatic exposure adjustments. However, most of the existing solutions focus on individual tasks or post-processing methods, e.g., image enhancement or cropping after the capture. However, they do not provide real-time guidance to users during image acquisition, which is important to improve composition at the source.

To address this limitation, we propose a Hybrid Deep Composition Optimization approach for real-time assistance in portrait photography. The proposed system combines deep learning-based subject detection with rule-based composition analysis to analyze several visual factors like spatial balance, illumination, saliency and alignment. We propose a new Adaptive Composition Similarity Index (ACSI) to combine these factors into one composition score for real-time feedback and guidance at the time of image capture.

The system also has lightweight models such as BlazeFace for light-weight face detection and MobileNetV2 for feature-based reference matching, which allows for both accuracy and real-time performance. Our method enables users to obtain practical suggestions like changing the subject's position, aligning the camera and adjusting the lighting to take well-composed portraits without the need for professional skills.

Unlike existing portrait photography assistance systems that primarily focus on post-processing enhancement, the proposed framework emphasizes real-time composition guidance through adaptive hybrid analysis and lightweight deployable models suitable for edge devices.

II. Key Contribution

We propose a hybrid framework that combines deep learning techniques with rule-based composition analysis for assisting portrait photography in real-time. The major contributions of this work are:

Hybrid Composition Optimization Framework: A new combination of deep learning-based subject detection and rule-based photographic composition principles for real-time evaluation of image aesthetics.

Adaptive Composition Similarity Index (ACSI) A unified scoring scheme is proposed to incorporate multiple composition factors, e.g. spatial balance, illumination consistency, saliency, line alignment, into a single quantitative metric for real-time feedback.

Multi-Module Computer Vision Pipeline: Modular System Design and Implementation for Face Detection (BlazeFace), Saliency Analysis, Dominant Line Detection, Illumination Evaluation and Spatial Composition Analysis

Real-Time Feedback and Guidance System: Creating a low-latency pipeline that processes live camera streams and provides actionable composition feedback (e.g. move subject, camera alignment, lighting)

Reference-Based Compositional Matching Features of the images taken using MobilenetV2 are extracted and matched with the reference images created by the professionals using cosine similarity.

Lightweight and Deployable Architecture The proposed system is able to run on edge devices efficiently processing without high computational resources and cloud based inference in real-time.

III. Proposed Methodology

The proposed system offers real-time portrait photography guidance by combining deep learning-based subject detection and rule-based composition analysis.

It is a multi-stage approach that combines subject detection, feature extraction, composition assessment and score aggregation into a single framework.

A. Subject Identification:

The system uses the BlazeFace model, a lightweight deep neural network for face detection in real-time, to find the main subject in each frame. The model output is the normalized bounding box coordinates with respect to the detected face region. If no face is detected, a fallback mechanism places a central bounding box so the process can continue. The subject area extracted is used as a reference for other modules of composition analysis.

B. Identification of main lines:

The system uses the Canny algorithm to detect edges and the Hough Line Transform (HoughLinesP) to identify the dominant lines in the image and evaluate the camera alignment and structural composition. The detected lines are analyzed for orientation and a line alignment score is calculated based on the percentage of horizontal lines. This score quantifies the stability of the camera orientation and contributes to the overall composition quality.

C. Saliency Map

And the saliency module determines whether the subject is salient from the background. The input frame is converted to gray scale and blurred with Gaussian blur to obtain a smoothed version. A subtraction map is created to bring out the high frequency details. The saliency score is the ratio of the mean intensity of the subject region to the global image intensity denoting the prominence of the subject.

D. Study of illumination

To estimate the lighting conditions, the input image is converted to the HSV color space, and the Value (V) channel is extracted, indicating brightness. To determine the uniformity and quality of the lighting the average brightness and standard deviation of the system are used. A consistency score is calculated to detect uneven lighting or hard shadows that reduce the quality of the composition.

E. Space balance (rule of thirds):

The spatial composition of the subject is analyzed by the rule of thirds. The center of the detected bounding box is compared against pre-defined grid intersection points. The Euclidean distance between the subject position and the closest grid intersection is normalized to obtain a spatial balance score. Classical composition: the more the better.

F. Adaptive Composition Similarity Index (ACSI):

The output of the individual modules is then fused using the Adaptive Composition Similarity Index (ACSI) to produce a single composition score. The ACSI is a weighted average of a number of factors:

- Line alignment grade
- Saliency Score
- Type of lighting
- Score of spatial equilibrium

Weights are adapted according to scene conditions (e.g. indoor vs. outdoor) for context-aware composition evaluation. Finally, the ACSI score is a number between 0 and 100 and serves as a numerical measure of the overall quality of the image composition.

G. Reference Based Feature Matching:

When an image is taken, the system extracts deep feature representations using MobileNetV2. The feature vector is then compared with a database of professionally taken portrait images by means of cosine similarity. This helps to find visually similar reference images and gives the user extra hints to improve composition style.

H. Providing Immediate Feedback:

The system employs the calculated ACSI score and outputs of single modules to give immediate feedback through visual overlays and textual recommendations. Suggestions include repositioning the subject, adjusting camera alignment and lighting. This is shown on the user interface to aid in the creation of a well-composed portrait.

IV. System Architecture

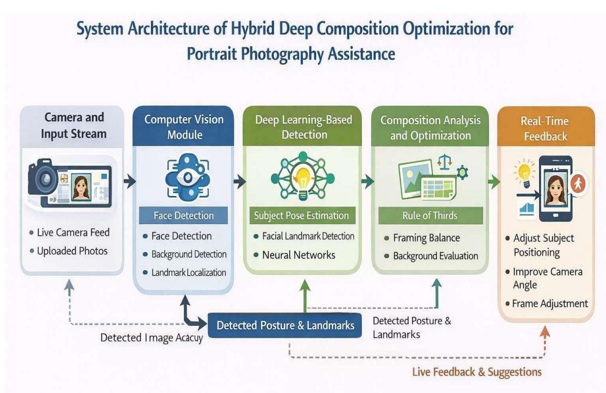

Figure 1. System Architecture of the Proposed Hybrid Portrait Photography Assistance Framework

In this paper, we present a modular real-time portrait photography assistance system built using computer vision and deep learning methods to analyze image composition and provide immediate feedback to users. The architecture generally consists of a front-end camera interface, a backend processing server and a multi-stage composition analysis pipeline.

The system starts with a camera input module. Live video frames are captured from a smart phone or webcam. These frames are encoded and sent to a backend server implemented in a lightweight Flask framework. Incoming frames are interpreted by the backend and passed through a set of processing modules for composition analysis.

The computer vision pipeline does a number of things per frame. The deep learning-based face detection module implemented by BlazeFace model detects the subject and extracts the bounding box coordinates. These coordinates are used as a reference for the next analysis stages. At the same time, other modules perform different compositional analyses such as dominant line detection, saliency estimation, illumination analysis and spatial balance assessment based on the rule of thirds.

The outputs of these modules are fused by the Adaptive Composition Similarity Index (ACSI), which computes a composite score using weighted contributions of each factor. The score is a measure of the aesthetic quality of the captured frame in general.

The system then provides real-time visual overlays and textual guidance, e.g., subject repositioning, camera alignment and lighting adjustments. The processed frame with the composition score and guidance information is then passed back to the front-end interface for display.

In addition, after the image is captured, a reference matching module is activated, where deep features extracted by MobileNetV2 are compared with a database of professional photographs using cosine similarity. This allows the system to propose visually similar reference images for further guidance.

The modular design of the system allows for scalability and efficient real-time performance so that the system can operate with low latency and run on edge devices such as smartphones and embedded camera systems.

V. Implementation Details

The proposed portrait photography assistance system is implemented using python based frameworks and computer vision libraries for real-time performance. The back-end processing is done by the Flask web framework which takes care of the processing of incoming requests from the front-end interface and manages the processing pipeline.

The front-end interface is intended to run on a browser with a camera module to capture live video frames. The frames are encoded as base64 images and sent periodically to the Flask backend for processing. The backend decodes the received image in a frame and sends this image to the composition analysis pipeline.

OpenCV library was used for image pre-processing, edge detection, overlay generation and visualization. Computer vision operations are performed using OpenCV. For face detection we use efficient and accurate MediaPipe BlazeFace model and works effectively for real-time applications.

The system consists of four analysis modules: line detection (Canny edge detection and Hough Line Transform), saliency estimation, illumination analysis based on HSV color space and spatial balance evaluation based on rule of thirds. Each module returns a normalized score, which are combined by the Adaptive Composition Similarity Index (ACSI) to obtain a final composition score.MobileNetV2 is used as a feature extractor for reference based composition matching in the system. Then the captured images are resized and feed to the network to get a 1280 dimension feature vector. The vector is then compared with pre-computed embeddings in a reference database to find visually similar professional portraits with cosine similarity.

The system has an average processing time of around 300-400 ms per frame, which enables near real-time feedback with an overlay refresh rate of about 4 frames per second. The feedback is given in terms of visual guides and text suggestions on the user interface which can help users in composing better shots before taking the picture.

The system is designed as modular so that it can easily include additional components and scale to be deployed on edge devices such as smartphones and embedded camera systems.

VI. Literature Survey

Recently, computer vision and machine learning approaches have been widely investigated for enhancing image composition and aesthetic quality in intelligent photography assistance. The early methods were mostly rule-based, inspired by traditional photographic principles such as the rule of thirds, symmetry, leading lines and the golden ratio. These techniques considered the spatial placement of subject and background elements to see if an image followed the conventional rules of composition. Such methods are interpretable and computationally efficient. However, they do not have the flexibility to handle complex scenes with multiple subjects, varying lighting conditions and dynamic backgrounds.With the development of deep learning, Convolutional Neural Networks (CNNs) have been widely used in aesthetic image assessment and scene understanding. CNN based models can directly learn hierarchical visual features [1][2], e.g. edges, textures, shapes and object semantics from large-scale datasets. Some studies have shown CNNs are effective for the image quality and aesthetic score prediction, by capturing high-level context information . However, these approaches are mainly data-driven and may lack interpretability as they do not explicitly impose classical composition rules.

Recent work has proposed hybrid methods that integrate deep learning approaches with rule-based composition analysis [16][17]. In these systems, deep models are used to recognize the semantic elements such as face, object and scene context and rule-based algorithms are used to evaluate the composition principles such as subject alignment, spatial balance and distribution of background. These hybrid approaches combine the benefits of both approaches, giving better accuracy and interpretability.Lightweight real-time vision architectures for edge-based deployment have also gained significant attention in recent years [18][19].

However, a limitation of the existing work is the focus on post-processing techniques. Many systems analyze or enhance image composition afterwards, with techniques like aesthetic scoring, filtering or automatic cropping. These techniques improve the quality of the final image, but they do not assist the user in the image capture process that is most important for composition decisions.

Guidelines for portrait composition are still relatively unexplored in the context of real-time photography assistance. During image acquisition, the ability to provide real-time feedback allows for on-the-fly adjustments, which greatly improves the user experience and image quality. This gap is filled by our proposed system, which presents a real-time hybrid composition optimization framework that combines deep learning-based subject detection with rule-based composition evaluation.

Unlike existing approaches, the proposed system combines lightweight deep learning models with interpretable rule-based composition evaluation and introduces the Adaptive Composition Similarity Index (ACSI) for dynamic real-time scoring. Additionally, the integration of reference-based composition matching using MobileNetV2 embeddings distinguishes the proposed framework from prior portrait assistance systems.

VII. DATASET DESCRIPTION

To validate practical applicability and controlled testing respectively, we evaluate the proposed system with a combination of real-time camera input and curated portrait image datasets. The primary input to the system is a stream of live video frames from a webcam or phone camera, allowing the composition to be analyzed in real-time while the image is being acquired. In addition to live input, we also use a dataset of reference images of professionally composed portrait images for feature based matching. The dataset is preprocessed to obtain deep feature representations with MobileNetV2, and the embeddings are saved in a serialized database to enable efficient similarity comparison at runtime. The reference dataset contains images with different composition styles, lighting conditions and subject placements to be robust in matching. A set of portrait images with different backgrounds and illumination conditions and subject orientations is used to test the system to detect subjects and evaluate the composition quality. These images are used for validation of individual modules such as subject detection, saliency estimation and spatial balance analysis.The dataset is intended to cover a range of real-world scenarios such as indoor and outdoor environments, different illumination intensities and different positions of the subjects. This allows the system to generalize well and provide reliable composition guidance under a variety of conditions. In this implementation, the system does not require large-scale supervised training, but the combination of real-time input and reference-based evaluation allows extensive testing of the proposed hybrid composition optimization framework.

VIII. RESULTS AND ANALYSIS

The proposed portrait photography assistance system was evaluated using a live camera input and a number of portrait images taken under different conditions. The evaluation aimed to measure the effectiveness of the hybrid composition optimization approach for subject detection, composition quality assessment and real-time feedback. The system was tested on real video frames, each frame being processed by the whole compositional analysis pipeline, including subject detection, saliency estimation, illumination analysis, dominant lines detection and spatial balance evaluation. The BlazeFace model could find the face areas and extract significant features such as face boundaries and face orientation that made the identification of the position of the subjects in the

frame accurate. To combine multiple visual factors, we propose the Adaptive Composition Similarity Index (ACSI) to compute an overall composition score for each frame. The score provided the system with a real-time feedback loop, indicating how to reposition the subject, align the camera and adjust the lighting. The system exhibited good performance in different lighting conditions and backgrounds, demonstrating the potential for real applications. We compare the results from the baseline CNN based approach with the proposed hybrid model. The results in Table I show that the hybrid method performs better in all evaluation metrics. The proposed model in particular achieved an accuracy of 93% whereas the CNN based model achieved 88%. The accuracy (91%) and recall (90%) improved in the same way, showing that the combination of deep learning and rule-based composition analysis is effective. The performance gain can be attributed to the complementary strengths of the hybrid approach. Deep learning models can learn the semantic information, e.g. facial features and scene context, while the rule-based modules utilize traditional composition rules, leading to more reliable and interpretable composition evaluations. Computationally , the system runs at an average processing speed of 300-400 ms/frame allowing for near real-time feedback with an overlay refresh rate of ~4 frames per second . This demonstrates the potential relevance of the system in practical photographic situations.
Analysis of errors: However effective this system may be, it is not without limitations. If there are multiple subjects in a scene, the model might focus on just the primary detected face and not the scene composition analysis. Extreme lighting conditions like overexposure or low light can also impact the scoring accuracy of lighting. The detection performance can also be degraded due to the limitations of face-detection model such as side-profile or partial occlusion of face. Experimental results demonstrate that the proposed hybrid deep composition optimization method is capable of obtaining better composition evaluation and practical real-time guidance, which is suitable for intelligent portrait photography assistance system.

TABLE I. PERFORMANCE COMPARISON BETWEEN CNN AND PROPOSED HYBRID MODEL

Model	Accuracy	Precision	Recall
CNN Model	88%	86%	85%
Hybrid Deep Model	93%	91%	90%

The hybrid deep learning approach demonstrated higher accuracy compared to traditional deep learning models, highlighting its effectiveness in portrait composition optimization.

IX. DISCUSSION

The experimental results show that the proposed hybrid framework effectively improves the performance of the portrait composition analysis in comparison to conventional CNN based approaches. Deep learning based subject detection is integrated with rule-based composition evaluation, allowing the system to acquire both semantic scene understanding and classical photographic principles. The Adaptive Composition Similarity Index (ACSI) is a key tool for improving interpretability by combining different composition factors into a single quantitative score. The proposed framework, in contrast to purely data-driven approaches, gives explainable feedback such as guidance for subject repositioning, lighting adjustment and camera alignment.
Lightweight models such as BlazeFace and MobileNetV2 are used to ensure low computational costs and real-time responsiveness, allowing the framework to be deployed on smartphones and edge-based devices.
The proposed approach is more orientated towards real-time guidance during image capture, increasing practical applicability and user interaction compared to existing photography assistance systems based on post-processing.
The proposed system achieves promising performance, but there are still challenges in multi-subject scenes, severe illumination variations and partial facial occlusions. These limitations suggest opportunities for future improvement.
These observations validate the effectiveness of combining lightweight deep learning models with interpretable rule-based composition analysis for intelligent photography assistance.

X. FUTURE RESEARCH

Further improvements can be done through the inclusion of state-of-the-art AI algorithms that increase accuracy and flexibility of the system. Some interesting ideas include incorporating transformer-based vision algorithms like Vision Transformers (ViT). Vision transformers can analyze image information better than traditional convolution-based approaches in regard to detecting spatial relations and global context. It will result in even more accurate analysis of the composition of an image. AR-based guidance systems can be another useful improvement for a potential solution to our problem statement. Furthermore, AR can be implemented in order to display composition rules, positioning frames and markers onto the interface of the camera during picture-taking. Users will be able to adjust the positioning of the object and camera position in real-time in order to ensure correct composition. Another aspect that could be considered in the future is implementing algorithms for estimating and correcting the intensity of light. With smart light analysis and correction, users would be able to adjust the brightness, contrast and direction of light, which are critical for creating portraits.

A major field for further investigation includes customization. Customization allows the system to study the personal preferences of the user and adapt its proposals according to the tastes of each individual. Composition suggestions can be modified using the images from the previous periods. Improvement of the system in terms of performance on edge devices and mobiles will contribute to enhanced performance. It will allow the process to occur in real-time without cloud computing, minimizing lag time and providing security and privacy through local computation on devices. Such an approach will facilitate the creation of smarter and more user-oriented photography guidance systems.

XI. CONCLUSION

In this paper, we presented a Hybrid Deep Composition Optimisation approach to real-time portrait photography assistance by integrating deep learning methods and rule-based composition analysis. The proposed system combines subject detection by lightweight neural models and multiple computer vision modules for evaluating key composition factors such as spatial balance, illumination, saliency and alignment.

A key contribution of this work is the introduction of the Adaptive Composition Similarity Index (ACSI) which provides a unified and quantitative measure of image composition quality. The system provides an effective real-time feedback and guidance during the image capture by fusing multiple visual features into a single score.The experimental results show that the proposed hybrid approach outperforms the conventional methods with higher accuracy and better capability of composition assessment. The system is low-latency, which is suitable for real-time applications and for the purpose of practical deployment.The proposed framework suggests actionable guidance to the users such as subject positioning, camera alignment and lighting adjustments to be able to capture aesthetically pleasing portraits without the need for professional expertise.In general, this work adds to the development of intelligent, real-time photography assistance systems and has potential applications in smart phones, smart cameras, and edge-based imaging platforms.

The proposed framework demonstrates the potential of integrating lightweight artificial intelligence models with real-time composition analysis to enhance next-generation intelligent photography systems.

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