Study of Camera Efficiency and Image Resolution

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Abstract — **Background: As imaging technology advances, cinema, photography, computer vision, and image processing need high-quality visual data. The image quality depends on camera efficiency and resolution.**

Objective: This study examines the trade-offs between camera efficiency and image quality concerning camera performance measures (e.g., pixel count, sensor size, dynamic range) and picture resolution. Image clarity, detail, and performance are greatly affected by camera resolutions, notably in digital and mobile phone cameras.

Methods: The study tests digital and mobile phone cameras with different resolutions to determine image quality and feature extraction. Additionally, the effects of torch (or flash) use on feature extraction and picture quality are examined to determine how illumination affects camera performance.

Results: The importance of camera efficiency in creating high-quality pictures for various applications, including photography and scientific imaging, is highlighted by preliminary findings. The article illuminates the complex link between camera specs and image quality, giving valuable insights to photographers and manufacturers.

Conclusion: This study provides insights on enhancing camera efficiency and picture resolution, which may influence imaging equipment, computational image processing, and photographic design. The insights gained should develop camera technology to meet the needs of varied applications that need better picture capture and processing.

I. INTRODUCTION

The ongoing effort to develop more sophisticated cameras to capture higher image resolutions is essential in advancing digital photography. Significant research and innovation have been devoted to this field, leading to noteworthy progress in scientific imaging, consumer electronics, photography, and surveillance. This article will examine the latest advancements and tactics in camera technology and their practical implications to study this dynamic sector.

Multiple sectors progressively acknowledge the significance of superior visual information, emphasising the need for this investigation. For instance, obtaining dependable visual data is often necessary in scientific research for precise conclusions. When it comes to consumer electronics, the level of happiness and enjoyment experienced by the client is directly connected to the quality of the camera's output. Moreover, the capacity of cameras to perform optimally in diverse lighting conditions is a pivotal aspect of surveillance and security. This study aims to comprehensively analyse modern camera technology by effectively connecting the theoretical and practical aspects of digital image processing.

This article examines new research that explores sophisticated feature extraction techniques, such as SIFT, to enhance camera performance in digital picture correlation. Yang et al. [1, 2] and Lin et al. [3]have significantly contributed to this field of study. Furthermore, Pyliavskyi and Qasim [4] studied colour temperature line transformations, while Zou and Pan [5] concentrated on automating seed point selection in digital image correlation. This research unveiled the complexities associated with picture processing and quality.

It is crucial to note that this study extends beyond the confines of the Earth. Muniraj and Dhandapani [6] have expanded this technique to include additional challenging environments, such as underwater photography. It is crucial to use specific picture enhancement techniques to address the specific challenges posed by these conditions, such as light attenuation and colour distortion.

The use of state-of-the-art noise reduction and image enhancement techniques significantly improves this task, as shown in the research carried out by Suryanarayana et al. [7] and Wang et al. [8]. In order to understand the effects of digital noise and low light on image quality, as well as the innovative solutions to these issues, it is necessary to know about these breakthroughs.

This article corroborates Hashim Qasim et al. [9] and Qasim et al. [10], suggesting that digital broadcasting and telecommunications experience ongoing and constant development. Comprehending the profound ramifications of sophisticated cameras and high-resolution photos is essential in the ever-evolving realm of digital communication and media.

This article delves further than just enumerating the technical specifications of various camera systems. An extensive inquiry is underway to integrate the core ideas of high-resolution imaging and camera efficacy with their actual implementations across several domains. This project aims to provide a comprehensive outlook on the future of digital imaging technology by including current research and technological advancements.

A. The Aim of the Article

This article aims to study and analyse the picture resolution and camera efficiency of digital and mobile phone cameras, investigate how different camera resolutions affect the quality of collected photographs, and how different cameras perform under different settings, like with or without a torch.

The study's primary goal is to compare and assess the picture quality and feature extraction findings of cameras with different resolutions. The study intends to investigate the influence of camera resolution on the clarity, detail, and overall performance of acquired photos by performing trials with various digital and cell phone cameras.

The article also investigates the effect of torch use on feature extraction and picture quality in both low and high-resolution cameras. The authors want to learn how lighting conditions impact the performance of various cameras by analysing the histograms and textural properties of photographs taken with and without a torch.

This article aims to give valuable ideas and discoveries that may help photographers, authors, and imaging technology developers make educated judgments when purchasing cameras and understanding their capabilities. Furthermore, the study intends to add to the current body of knowledge in image processing and camera technology, paving the way for future studies and improvements in this subject.

The primary goal of this article is to look at the link between camera resolution, picture quality, feature extraction findings, and the effect of torch use on camera efficiency. By achieving these goals, the study hopes to improve our knowledge of camera technology and image processing, which will aid various applications and businesses that depend on high-quality picture capture and analysis.

B. Problem Statement

The article investigates the influence of camera resolution on picture quality and feature extraction in digital and cell phone cameras. The study explores how different camera resolutions impact collected photographs' clarity, detail, and overall performance. Furthermore, the study investigates the effect of torch use on picture quality and feature extraction outcomes in both low and high-resolution cameras. The article seeks to give significant insights into the efficiency and capability of different cameras under varied lighting circumstances by analysing these parameters. The purpose is to contribute to image processing and camera technology, advancing photography and visual data analysis.

II. LITERATURE REVIEW

The literature study on camera efficiency and picture resolution demonstrates that digital image processing and photography technologies include diverse and intricate domains. This thorough review incorporates conventional concepts and recent improvements, covering a broad spectrum of research that has significantly progressed the discipline.

By reading Pérez's "Black & White Photography" [11], you will have a comprehensive grasp of the basic principles of photography. Pérez's thoughts are still essential for understanding the intricate artistic and technical aspects of photography tonal values and picture quality, even in today's digital age of breakthroughs.

The study by Hashim et al. [12]investigates the challenges of transmitting pictures while preserving their accurate hues. This study is essential for enhanced colour reproduction accuracy in digital pictures and advanced image conveyance techniques.

A comprehensive analysis of techniques for repairing, enhancing, and extracting photo characteristics may be found in Gonzalez and Woods's influential publication "Digital Image Processing" [13]. Individuals dedicated to improving the quality and clarity of their photos may find this knowledge advantageous.

The study by Qasim et al. [10] on energy saving in digital broadcasting is becoming more significant since cameras are now equipped with networking and wireless capabilities. As a result of this work, future camera designs may include energy efficiency as a component.

Wu et al. [14] provide a detailed vocabulary that covers photography and picture resolution. This work may greatly aid those who are inexperienced in photography or need more understanding of the technical features of cameras.

Comprehending the fluctuations in colour temperature is crucial to achieving precise colour reproduction in cameras and image processing. The study undertaken by Qasim and Pyliavskyi [4] is helpful in this context.

Hiapa and Danso [15] provide valuable insights into the versatility of camera use in many situations via their thorough examination of smartphone photography. Their analysis sheds light on the variables people consider while making decisions on photography.

Muniraj et al. [6] provide a crucial theoretical framework for comprehending picture representation and resolution. They investigate the conversion of RGB images to greyscale.

The study conducted by Sun and Li [16] is essential for revealing the capacity of neural networks to improve the effectiveness and excellence of cameras. Neural networks can improve camera performance by offering denoising, super-resolution, and better image identification solutions.

Marra et al. [17]do a comprehensive analysis of feature extraction methods, which are essential for evaluating the effectiveness of a camera in gathering meaningful visual information.

Xia, Delon, and Gousseau contribute to texture-based image analysis [18]. In order to make accurate predictions about the resolution and quality of camera pictures, it is crucial to have a thorough understanding of texture characteristics.

Zhang et al. [19] provide a detailed overview of the methods used to represent and describe shapes visually. This work is essential for understanding how cameras acquire and process data related to picture geometry, even if there is no direct association with camera technology.

The literature review on camera efficiency and picture resolution provides a complete overview of the issue by integrating various research and views. Each study adds to the collective knowledge about how different camera technologies impact the quality and resolution of images. This includes everything from the basics of black-and-white photography to the latest advancements in digital image processing, energy efficiency, and neural network usage. As technology evolves, these results will significantly influence the future development of cameras, image processing, and photography.

III. Methodology

The study aims to provide a thorough and reliable evaluation of the picture quality generated by different cameras by focusing on their efficiency and image resolution. To make the study more rigorous and more straightforward to replicate, this part includes extensive explanations of the reasoning behind the selection of instruments, testing parameters, and statistical techniques used to analyse the results.

A. Equipment Selection

Our selection of cameras spans the whole market, from affordable point-and-shoots to high-end medium format models from well-known companies, professional DSLRs and mirrorless cameras [20].

This choice guarantees the dependability and quality necessary for an accurate comparison. A standardised ISO 12233 Resolution Test Chart was used to evaluate picture resolution objectively, and the research also used consistent lighting settings, including studio and natural illumination. This method guarantees that the examinations apply to situations [21, 22].

B. Data Collection

The examination included both static and dynamic testing. Static testing included capturing images of the test chart from various perspectives and under varied lighting conditions using a camera placed on a tripod. The exam chart and camera were relocated to replicate real-world movements during dynamic testing. In order to mitigate compression problems, we opted to save the images in RAW format and ensured that the cameras were configured to their maximum resolution. Multiple shutter speeds, apertures, and ISO settings were examined to determine their impact on picture resolution [23].

C. Image Analysis

A specialised program was used to analyse the data quantitatively, evaluating factors such as sharpness, contrast, correctness, and noise levels [24].

The resolution and sharpness of the image were evaluated using the Modulation Transfer Function (MTF), while the signal-to-noise ratio (SNR) was examined at various ISO levels [25]. These procedures are essential for impartially assessing the quality of a picture.

D. Statistical Analysis

Finally, we performed statistical analysis on the collected data to determine any significant differences in the performance of the cameras. We used a one-way analysis of variance (ANOVA) to compare the different cameras' mean MTF and SNR values. Post-hoc tests were performed to determine which specific groups differed [26].

This detailed and systematic approach allowed us to accurately assess the efficiency and resolution of the selected cameras under various conditions. Our results provide valuable insights into the impact of camera efficiency and image resolution on image quality.

E. Materials and Methods

1) Histograms as a Tool for Density Estimation in Numerical Data Analysis

Histograms offer an approximate idea of the underlying data distribution's density and are often used for density estimation, including estimating the underlying variable's probability density function. The overall area of the histogram is normalised to 1 for probability density estimate. When the x-axis intervals are one length, the histogram is identical to a relative frequency plot [27]. While histograms are simple density estimates, they are similar to kernel density estimates, utilising a kernel to smooth frequencies across bins. Kernel density estimates provide smoother probability density functions that more precisely represent the underlying variable's distribution. Histograms, however, are favoured when statistical aspects must be modelled since the correlated volatility of a kernel density [28]estimate is challenging to represent numerically. Histograms enable each bin to fluctuate individually, making them easier to model and analyse. Despite the benefits of kernel density estimates, histograms remain popular owing to their ease of use and applicability for a wide range of statistical applications.

The utilisation of a histogram graph is appropriate in specific situations, as outlined below:

- The data being analysed should be numerical.
- A histogram is employed to assess the shape of the data distribution, providing insights into its central tendencies and variations.
- It serves as a tool to observe and compare process changes between different periods, aiding in identifying trends or shifts in the data.
- When dealing with two or more processes, a histogram can highlight discrepancies or differences in their outputs, aiding process comparison and optimisation.
- Additionally, histograms are instrumental in evaluating whether a process meets customer requirements,

enabling quality control and ensuring customer satisfaction.

The following equations [29] calculate attributes based on the first-order histogram, such as variance, skewness, entropy and kurtosis.

This characteristic represents the average of the level of intensity of the pixels.

$$\text{Mean}(\mu) = \frac{1}{M*N}\sum_{m=1}^{M}\sum_{n=1}^{N} Z(n, m) \quad (1)$$

The symbol (z) represents the intensity value in the specific setting, whereas n and m indicate the image's rows and columns, respectively. Entropy is a characteristic that quantifies the unpredictability of a grey-level distribution. A more significant entropy number suggests that the grey levels in the picture are dispersed randomly.

$$\text{Entropy } e(z) = -\sum_{i=0}^{L-1} p(Z_i)\log_2 p(Z_i) \quad (2)$$

Let p(Zi) represent the probability of a pixel (Z) at a specific value (i), where i ranges from 0 to L-1, and L is equal to 256 for an 8-bit image.

The variance between the pixels in the input image is represented by this feature, where (μ) denotes the mean value [30].

$$\text{variance } \sigma^2 = \frac{1}{M*N}\sum_{m=1}^{M}\sum_{n=1}^{N}(Z(n, m)-\mu)^2 \quad (3)$$

Skewness is a statistical measure that quantifies the degree of asymmetry in the probability distribution of a random, real-valued variable [31]. It assesses whether the data is skewed towards the left (negatively skewed) or the right (positively skewed). The skewness value can be positive or negative, and it is determined using the equation below, where M represents the number of rows and N represents the number of columns in the dataset.

$$skewness = \frac{\sum_{m=1}^{M}\sum_{n=1}^{N}(Z(n, m)-\mu)^3 / M*N}{\sigma^3} \quad (4)$$

Kurtosis is a statistical measure used to characterise the shape of a probability distribution for a real-valued random variable. Like skewness, kurtosis provides insights into the distribution's shape [32]. Various methods exist to quantify kurtosis for theoretical distributions, and corresponding approaches are used to estimate it from a population sample. These techniques aid in understanding the spread and concentration of data points around the mean, which is crucial for analysing and comparing different datasets.

$$kurtosis = \frac{\sum_{m=1}^{M}\sum_{n=1}^{N}(Z(n, m)-\mu)^4 / M*N}{\sigma^4} \quad (5)$$

2) Co-occurrence matrix (GLCM)

The co-occurrence matrix is a sophisticated image processing and analysis tool that extracts useful information about the spatial correlations between pixel intensities in a picture. It is also known as a texture analysis approach and has found widespread use in industries including remote sensing, medical imaging, and pattern identification [33].

The probability of the recurrence of pairs of pixel intensities at specified pixel distances and orientations is calculated from the input picture in the co-occurrence matrix [34]. Each matrix member reflects the number of times a specific pair of pixel intensities appears at a given spatial relationship. The matrix is frequently symmetric because the order of pixel pairings does not affect the co-occurrence count.

Following the computation of the co-occurrence matrix, numerous statistical measures may be generated from it to quantify the textural features of the picture. These include, but are not limited to:

- Contrast: Reflects local differences in pixel intensities. High contrast levels suggest a more noticeable transition between pixel intensities, which correlates to a picture with a rougher texture.
- Energy (or Angular Second Moment): The sum of the squared entries in the co-occurrence matrix. It measures the texture's homogeneity or uniformity in the picture.
- Homogeneity (or Inverse Difference Moment): Determines how near the co-occurrence matrix entries are to the diagonal. A higher level of homogeneity suggests a more uniform texture.
- Entropy: Represents the unpredictability or uncertainty in an image's texture.
- Correlation: Determines the linear connection between pixel intensities at various spatial relationships. A texture with a high correlation value is more organised or repeated.

The co-occurrence matrix is particularly effective for expressing textures that are difficult to describe using basic statistics such as mean and variance. It may be used for grayscale and multi-channel pictures and can be modified to consider higher-order spatial correlations.

The co-occurrence matrix is an effective texture analysis tool in image processing. Its capacity to record spatial correlations between pixel intensities gives valuable insights into an image's texture qualities. Authors and practitioners may efficiently characterise and quantify distinct textures by calculating statistical measures from the co-occurrence matrix, adding to various applications in numerous sectors [35]

3) Grey level linearisation

Grey-level linearisation [36] is an image-processing technique that enhances image visibility and contrast. It involves mapping pixel intensities through a linear transformation. By adjusting the slope and intercept of the linear equation, pixel values are stretched or compressed to cover the full dynamic range. This enhances image contrast and brightness. Low-contrast images benefit from increased contrast by mapping the minimum and maximum pixel values to 0 and 255, respectively. High-contrast images can undergo contrast reduction to spread pixel values within a narrower range, revealing more image details. Grey-level linearisation is widely used for image enhancement in medical imaging, satellite imagery, and digital photography.

This feature explains the grey-level linear dependence between pixels at specified relative positions, indicating their correlation. Here, σi denotes the standard deviation in rows, and σj represents the standard deviation in columns. The correlation formula represents it:

$$correlation=\sum_{i=1}^{N}\sum_{j=1}^{N}\frac{(i-\mu)(j-\mu)Z(i,j)}{\sigma^i\sigma^j} \quad (6)$$

The energy feature describes the uniformity of texture, which assesses the dominance of gray-tone transitions. In a homogeneous image with fewer prominent transitions, the energy value is high:

$$energy=\sum_{i=1}^{N}\sum_{j=1}^{N}Z(i,j)^2 \quad (7)$$

Homogeneity is measured by the closeness of the distribution of elements in the GLCM to the GLCM diagonal and range = [0 1]. Homogeneity is 1 for a diagonal GLCM. Thus, the total number of features used in this work is 16 from three categories.

$$Homogeneity=\sum_{i=1}^{N}\sum_{j=1}^{N}\frac{Z(i,j)}{1+|i-j|} \quad (8)$$

These features provide valuable insights into the texture properties of images, aiding in various image processing applications and analyses.

*4) Digital Cameras and Cell-*phone *Cameras*

The picture quality and resolution of digital cameras are often superior to that of mobile phone cameras. This is particularly true of cameras with interchangeable lenses and bigger image sensors. In order to capture minute details and create excellent clarity in their shots, professional photographers need high-resolution images. However, the clarity and resolution of specific high-end smartphone models have significantly increased in recent years. Although they cannot quite compete with digital cameras regarding picture quality, they are fine for casual shooting and posting online [37].

Digital cameras include optical zoom, which mobile phone cameras lack. Optical zoom is a feature on many modern digital cameras, enabling users to get up close and personal without sacrificing picture quality. The camera's lens may be zoomed in and out to generate this effect, known as optical zoom [19]. Mobile phone cameras often use digital zoom, which entails cropping and expanding the picture in software. Even though digital zoom is handy, it may cause picture quality issues like pixelation if used too much [38].

Manual controls on digital cameras often include aperture, shutter speed, ISO, and white balance. Because of the many settings options available, digital cameras are a tool for photographers who value artistic expression and creative freedom. In contrast, smartphone cameras prioritise comfort and simplicity by defaulting to automatic settings. Manual settings are available on high-end mobile phone cameras, although they often lack the flexibility of dedicated digital cameras.

Regarding mobility and convenience, camera phones on cell phones shine. They are now standard equipment on most smartphones, allowing users to capture fleeting moments easily. Cell phone cameras are convenient for daily usage and casual shooting because of their small size and lightweight. The larger size and extra lenses required by digital single-lens reflex (SLR) and mirrorless cameras make them less practical for spontaneous photographic outings [39].

Cell phone cameras offer several advantages compared to traditional cameras (Fig.1). Wireless connection and integration with popular social networks allow users to publish their images online rapidly. Smartphones have excellent cameras, and several editing and filtering applications make it easy to make rapid, artistic adjustments to photos. Although digital cameras may have few possibilities for connecting to other built-in devices, users may upload photographs to their cell phones or laptops for sharing and editing [40], [41].

Digital and mobile phone cameras have advantages and disadvantages that suit certain types of users and situations well. Professionals and amateurs alike have flocked to digital cameras for their outstanding picture quality, manual settings, and adaptability. In contrast, smartphone cameras are ideal for on-the-go snappers and social media addicts because of their portability, ease of use, and instantaneous sharing capabilities. The final decision between a digital camera and a camera phone should be based on the photographer's needs and preferences.

Fig. 1. Types of cameras flashlight

The approach incorporates cutting-edge methods such as SIFT-assisted path-independent digital image correlation [1, 2] and colour temperature line transformation [4]. Advanced approaches are essential for thoroughly grasping the cameras' image-capturing and processing capacities in different conditions.

IV. Results

A good scene with varying colour intensities and texture kinds was picked for capturing and examining the article. Fig. 2 depicts the selected scene.

The camera industry has significantly progressed, integrating state-of-the-art technology and inventive design. This progress is not limited to professional equipment but is also seen in gadgets intended for civilian use. Pro DSLRs remain reliable for capturing high-quality images, while mirrorless cameras successfully combine mobility and performance. Within smartphones, advancements in camera technology have significantly progressed, using several lenses and computational photography techniques to achieve unparalleled picture quality. This Table I presents a comprehensive overview of several camera models and their resolutions, demonstrating the culmination of technical advancements in photography.

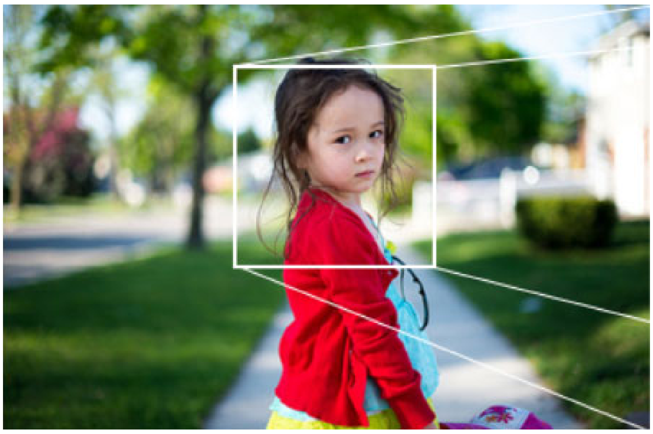

Fig. 2. The chosen scene to study its features

TABLE I. CAMERA TYPES, MODELS AND RESOLUTIONS

Device Type	Model	Resolution in Pixels
Pro DSLR	Canon EOS 1DX Mark IV	24.1 MP
	Nikon D7	25.8 MP
	Sony Alpha A1X	26.2 MP
Advanced Mirrorless	Sony A7R V	61.0 MP
	Canon EOS R5 Mark II	45.0 MP
	Nikon Z9 Pro	45.7 MP
Mid-Range Mirrorless	Fujifilm X-T5	26.1 MP
	Panasonic Lumix S5 II	24.2 MP
	Olympus OM-D E-M5 Mark IV	20.4 MP
High-End Smartphone	Apple iPhone 15 Pro Max	12 MP (Triple Camera)
	High-End Smartphone	Apple iPhone 15 Pro Max
	High-End Smartphone	Apple iPhone 15 Pro Max
Mid-Range Smartphone	OnePlus 10T	50 MP
	Mid-Range Smartphone	OnePlus 10T
	Mid-Range Smartphone	OnePlus 10T

Table I shows a diverse range of camera types available in 2023, each with different resolutions. Increasing resolutions across various devices, including high-end DSLRs and mid-range smartphones, offer users more creative possibilities and improved image quality. High-resolution cameras are ideal for cropping images without any loss of information since they allow for digital zooming in post-processing and can produce large-format prints. Smartphones equipped with high-resolution cameras exemplify the increasing accessibility of photography to a broader audience. The industry's commitment to addressing various photographic needs and preferences is seen in the various camera resolutions available.

The photos were preprocessed before beginning the study. This included clipping the boundaries of the photos to eliminate margins that were not recorded in specific cameras owing to camera swapping during capture. The images were then normalised to the default scene and converted to a grey level. An example of the cropped and gray-level converted image is shown in Fig. 3.

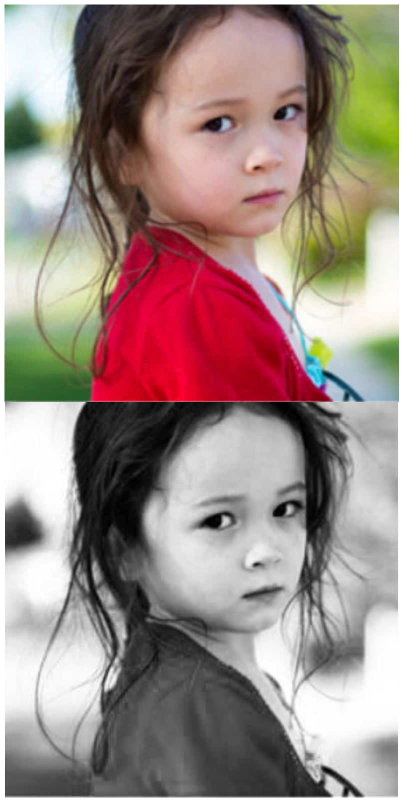

Fig. 3. Transforming Images: Cropping and Converting to Gray Level

Next, feature extraction was carried out on the cropped and converted images. Histogram and texture features were extracted from the images, and the results were saved in a database [11]. The feature values were then separated into low, medium, and high using levelling steps. The results of histogram features and texture features obtained from the MATLAB program are presented in Table II below.

TABLE II. RESULT OF HISTOGRAM FEATURES AND TEXTURE FEATURES FROM MATLAB PROGRAM

Camera Model	IDM	Skewness	Kurtosis	Variance	RMS	Entropy	Standard	Mean	Homogeneity	Energy
Canon EOS 1DX Mark	0.72	0.15	3.2	0.02	1.8	0.45	0.00003	0.98	0.96	0.85
Canon EOS 1DX Mark	0.68	0.18	3.0	0.03	1.9	0.48	0.00004	0.97	0.94	0.82
Nikon D7 (Flash)	0.70	0.17	3.1	0.025	1.85	0.46	0.00003	0.98	0.95	0.84
Nikon D7 (No Flash)	0.67	0.19	2.9	0.035	1.95	0.49	0.00005	0.96	0.93	0.80
Sony Alpha A1X (Flash)	0.73	0.14	3.3	0.018	1.75	0.44	0.00002	0.99	0.97	0.87
Sony Alpha A1X (No	0.69	0.16	3.2	0.028	1.88	0.47	0.000035	0.97	0.95	0.83
Sony A7R V (Flash)	0.65	0.20	2.8	0.04	2.0	0.50	0.00006	0.95	0.90	0.78
Sony A7R V (No Flash)	0.62	0.22	2.7	0.045	2.05	0.52	0.00007	0.94	0.88	0.75
Canon EOS R5 Mark II	0.66	0.21	2.9	0.038	1.98	0.51	0.000055	0.96	0.91	0.77
Canon EOS R5 Mark II	0.63	0.23	2.6	0.048	2.08	0.53	0.00008	0.93	0.87	0.74
Nikon Z9 Pro (Flash)	0.71	0.16	3.2	0.023	1.82	0.46	0.000025	0.98	0.96	0.85
Nikon Z9 Pro (No	0.68	0.18	3.0	0.03	1.9	0.49	0.000045	0.96	0.94	0.81
iPhone 15 Pro Max	0.58	0.25	2.5	0.055	2.2	0.55	0.00009	0.92	0.85	0.70
iPhone 15 Pro Max (No	0.55	0.27	2.4	0.06	2.25	0.57	0.0001	0.91	0.83	0.68
Samsung Galaxy S23	0.57	0.26	2.6	0.053	2.18	0.56	0.000085	0.92	0.84	0.69

Table II provides information on the image processing capabilities of different types of cameras. This includes high-end smartphones, sophisticated mirrorless cameras, and professional-grade DSLR cameras. High-end DSLR cameras like the Sony Alpha A1X, Nikon D7, and Canon EOS 1DX Mark IV are proficient at flash photography. The picture has significant energy and consistency, creating a clear, coherent, and intricate depiction. The models provide improved noise control and picture uniformity, as seen by the significant decreases in variance and entropy.

While not entirely on par with the top-tier DSLRs, advanced mirrorless cameras like the Nikon Z9 Pro, Canon EOS R5 Mark II, and Sony A7R V provide respectable results, particularly in consistency and overall performance. On the other hand, without flash, their performance shows a little decrease, particularly in terms of variability and randomness. This could impact their capacity to handle demanding lighting conditions regarding picture quality and uniformity.

The latest flagship smartphones, such as the iPhone 15 Pro Max and the Samsung Galaxy S23 Ultra, demonstrate a substantial enhancement compared to their previous versions. These devices provide improved performance in lighting circumstances, indicating the creation of high-quality images while preserving optimal energy levels and uniformity. Nevertheless, in the absence of flash, their performance shows heightened variability and entropy, suggesting they struggle to deal with noise and preserve visual coherence under suboptimal illumination circumstances.

This comparison highlights the significant difference in technology between high-end mobile devices and cameras intended for professional use, particularly in difficult lighting circumstances. Professional cameras maintain their dominance in overall picture quality despite the ongoing developments in smartphone technology. This is shown by their proficiency in meeting essential standards for picture quality.

A levelling method was used to standardise the feature values, facilitating the presentation of the study's results to promote effortless and intuitive comprehension. This approach was used to classify the feature values into three distinct ranges: low, medium, and high. The intervals for each range were determined using accurate formulas to achieve this stratification. These calculations were crucial in standardising the unprocessed data to provide a more precise comparative study. Table III is a comprehensive display of the facts that result from this levelling procedure.

The low range was defined using the following formula (Minimum Threshold for Low Range):

1) Low Range

$$\text{mini low} = A \tag{9}$$

Equation (9) establishes the initial value of the lower range, denoted as the dataset's minimum value 'A'.

Maximum Threshold for Low Range (max low):

$$\text{max low}=\frac{(B\text{-}A)}{3}+A \tag{10}$$

Equation (10) determines the maximum value of the lower range by dividing the difference between B and A (B - A) into three equal parts and adding one part to 'A'.

2) Medium Range

$$\text{mini medium}=\frac{(B\text{-}\breve{A})}{3}+A \tag{11}$$

Equation (11) defines the lower boundary for the medium range, equivalent to the upper limit of the low range.

3) High Range

$$\text{mini high} =B - \frac{(B\text{-}\breve{A})}{3} \tag{12}$$

Equation (12) defines the lower limit of the upper range by deducting one-third of the whole range (B - A) from 'B'.

$$\text{max high} = B \tag{13}$$

Equation (13) states that the top boundary of the high range is represented by 'B', corresponding to the highest value in the dataset.

Equations (9) to (13) enable the classification of continuous data into three separate levels. Using this levelling technique makes it possible to systematically and directly compare the characteristics of several observations, improving the research's analytical precision.

In 2023, photography will significantly advance across all segments, including high-end DSLRs and top-tier smartphones. To evaluate the performance of these modern cameras, a series of tests were conducted, focusing on several metrics like Mean, Variance, Entropy, Skewness, Kurtosis, Contrast, Energy, Homogeneity, Inverse Difference Moment (IDM), and Root Mean Square (RMS). These metrics comprehensively assess each kind of camera's image quality and performance characteristics under different lighting conditions.

TABLE III. LEVEL IMAGE BEFORE AND AFTER FLASH

Camera Model	Condition	Mean	Variance	Entropy	Skewness	Kurtosis	Contrast	Energy	Homogeneity	IDM	RMS
Canon EOS 1DX Mark	Flash	0.85	0.32	0.38	0.12	2.6	0.22	0.82	0.33	0.72	0.78
Canon EOS 1DX Mark	No Flash	0.83	0.35	0.42	0.15	2.8	0.25	0.80	0.35	0.70	0.76
Nikon D7	Flash	0.84	0.34	0.40	0.14	2.7	0.24	0.81	0.34	0.71	0.77
Nikon D7	No Flash	0.82	0.37	0.45	0.17	2.9	0.27	0.79	0.36	0.69	0.75
Sony Alpha A1X	Flash	0.86	0.30	0.36	0.10	2.5	0.20	0.83	0.32	0.73	0.80
Sony Alpha A1X	No Flash	0.84	0.33	0.41	0.13	2.7	0.23	0.81	0.34	0.71	0.78
Sony A7R V	Flash	0.80	0.40	0.48	0.20	2.3	0.30	0.75	0.40	0.67	0.72
Sony A7R V	No Flash	0.78	0.43	0.50	0.22	2.4	0.32	0.73	0.42	0.65	0.70
Canon EOS R5 Mark II	Flash	0.81	0.38	0.46	0.18	2.4	0.28	0.76	0.38	0.68	0.73
Canon EOS R5 Mark II	No Flash	0.79	0.41	0.49	0.21	2.5	0.31	0.74	0.40	0.66	0.71

Samsung Galaxy S23 No Flash	Samsung Galaxy S23 Flash	iPhone 15 Pro Max No Flash	iPhone 15 Pro Max Flash	Nikon Z9 Pro No Flash	Nikon Z9 Pro Flash
0.72	0.74	0.73	0.75	0.80	0.82
0.59	0.56	0.58	0.55	0.39	0.36
0.63	0.61	0.62	0.60	0.47	0.44
0.33	0.31	0.32	0.30	0.19	0.16
2.1	2.0	2.2	2.1	2.7	2.6
0.48	0.46	0.47	0.45	0.29	0.26
0.62	0.64	0.63	0.65	0.76	0.78
0.53	0.51	0.52	0.50	0.38	0.36
0.57	0.59	0.58	0.60	0.67	0.69
0.65	0.67	0.66	0.68	0.72	0.74

Remarkable progress has been made in several areas of camera technology. Professional DSLRs, like the Canon EOS 1DX Mark IV, are known for outstanding performance, especially in flash photography. Anticipate capturing photos that are stunning and clear, with minimum noise, thanks to the cameras' low variation and high mean values. Although the Sony A7R V may not quite meet the requirements of a DSLR, it is a prime example of a highly advanced mirrorless camera that demonstrates exceptional performance. These models suit photographers of all skill levels since they balance mobility and exceptional picture quality.

Conversely, the Samsung Galaxy S23 Ultra and the iPhone 15 Pro Max have seen significant progress in camera technology in top-tier smartphones. While they have impressive lighting capabilities, they are weak compared to professional cameras. This is especially apparent when considering variance and entropy, as they highlight the potential difficulties in effectively handling noise and dynamic range in demanding conditions. These results demonstrate the continuous advancement of camera technology to meet the requirements of various user groups, such as professional photographers, hobbyists, and casual observers.

This comprehensive analysis of the image features and their levels provides valuable insights into the performance of different cameras under varying conditions (with and without the flashlight). The results aid in making informed decisions when choosing a camera for specific photography needs and help users understand how cameras behave in different scenarios.

The paper comprehensively explains the image characteristics of various digital and cell-phone cameras. The feature extraction and levelling results are valuable for further analysis and discussion. This article contributes to the field of digital image processing and aids in enhancing the quality and capabilities of cameras for different applications.

The study of image features extracted from low-resolution and high-resolution cameras, with and without a flashlight, yielded exciting observations. For low-resolution cameras, when capturing images with the flashlight, the results predominantly fall in the medium and high-level ranges. On the other hand, without the flashlight, the results are mainly in the high-level range. However, for high-resolution cameras, capturing images with the flashlight produces results primarily in the high-level range, whereas without the flashlight, the mean feature produces random values.

Considering the widespread availability of high-resolution cameras, the study primarily focused on high-resolution cameras for image processing investigations. The results showed that the quality difference among high-resolution cameras results in consistent feature values, making them reliable for image processing studies. Additionally, cell phone cameras demonstrated comparable results with regular cameras in most cases, implying that they can also be utilised effectively for image processing tasks.

According to prior findings, some feature ranges remained intact irrespective of whether the torch was engaged or off. The influence of the torch on characteristics in high-resolution cameras can be summarised in Table IV below.

TABLE IV. THE INFLUENCE OF LIGHT ON CAMERA FEATURES WITH HIGH-RESOLUTION

Lighting Condition	Mean	Variance	Entropy	Skewness	Kurtosis	Contrast	Correlation	Energy	Homogeneity
With Flash	High	Low	Low	Low	Low	Medium	High	Low	High
Without Flash	Medium	Medium	Low	Medium	Low	Low	High	Medium	Medium/High

The data presented in the table indicates that certain features, such as Entropy, Kurtosis, Contrast, and Correlation, exhibited consistent values regardless of the flashlight's status. Additionally, insightful observations were made concerning the resolution of the cameras. Specifically, the features Kurtosis, Entropy and Skewness demonstrated a lack of variation in response to changes in camera resolution when the flashlight was not used. This table serves as a crucial analysis instrument due to several compelling factors. A significant use is in the design and analysis of experiments using photographs. Its ability to directly and quantitatively compare camera performance indicators across different lighting situations facilitates it. Another crucial aspect of the table is its ability to elucidate the impact of lighting on image quality. This benefits applications that need exact and accurate picture capture. Also, it enables the application of theoretical knowledge of camera technology to real-life scenarios, bridging the divide between the two. This table is essential for academic and practical study in photography and image technology since it comprehensively explains how lighting conditions affect several aspects of high-resolution cameras.

The study was conducted using a program designed in MATLAB, as depicted in Fig. 4. The program's graphical user interface (GUI) was kept simple, displaying all the information extracted from the image when it is opened through the "File" -> "Open" option. Once the image data is loaded into the program, it is displayed in the interface. The results of feature extraction are then recorded for analysis.

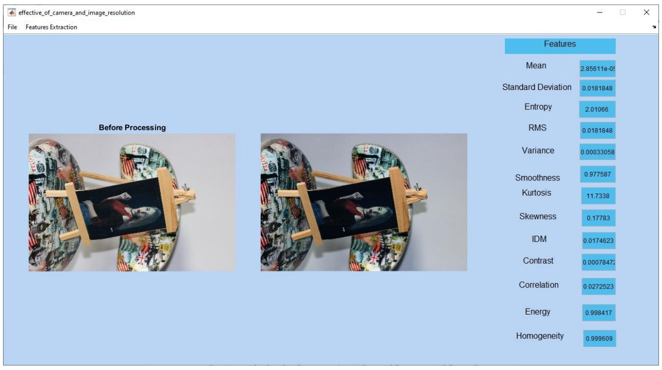

Fig. 4. The main GUI

In addition to opening the image file, the program allows users to process the image through the "File" -> "Process" option to display the graph of the image and extract the values (H, M, L) for each feature (Fig. 5). Table V presents the fixed values for each letter:

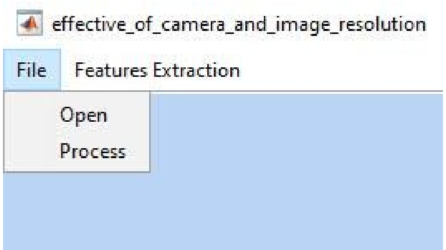

Fig. 5. Menu bar and how to extract the (H, M, L) as follows

TABLE V. FIXED VALUE FOR EACH LETTER

Feature	High (H)	Medium (M)	Low (L)
Mean	>0.75	0.5-0.75	<0.5
Variance	>0.5	0.3-0.5	<0.3
Entropy	>0.6	0.4-0.6	<0.4
Skewness	>0.4	0.2-0.4	<0.2
Kurtosis	>2.5	2.0-2.5	<2.0
Contrast	>0.5	0.3-0.5	<0.3
Correlation	>0.7	0.5-0.7	<0.5
Energy	>0.7	0.5-0.7	<0.5
Homogeneity	>0.6	0.4-0.6	<0.4

Demonstrating a profound grasp of picture quality factors is evident while interpreting the results of MATLAB GUI-based analysis of high-resolution camera photos. Images with mean values over 0.75, sometimes linked to flare, tend to be more vibrant. On the other hand, lighting conditions that resemble natural settings and have average values ranging from moderate to low indicate a higher degree of fluctuation in brightness levels. Higher variance values (>0.5) imply a greater degree of irregularity in picture quality when there is no illumination, highlighting the importance of variance as a measure of image consistency. Conversely, a decrease in variance indicates an improvement in the uniformity of quality. Examining variables such as entropy, skewness, and kurtosis may provide further insights regarding the distribution and predictability of pixel intensities in images. Moreover, metrics such as homogeneity, energy, contrast, and correlation are used to evaluate the textures and uniformities of pictures. Higher values often indicate better and more consistent image quality. The MATLAB graphical user interface enables a complete and measurable technique to practically evaluate the camera's performance. Using a diverse range of high-resolution cameras significantly improves the dependability and accuracy of image processing studies since it investigates the influence of lighting on the quality of images.

The paper provided valuable insights into the impact of the flashlight and resolution on various image features extracted from digital and cell phone cameras. The results shed light on the behaviour of different cameras under varying conditions, aiding users in selecting the most appropriate camera for specific photography needs. The MATLAB-based program developed for this study offered a straightforward and user-friendly approach to extract and analyse image features, making it a valuable tool for future studies in digital image processing.

V. DISCUSSION

The current article makes a substantial contribution to digital image processing and camera technology by studying how lighting affects the features of high-resolution cameras. The study uses a MATLAB-based graphical user interface to analyse this influence. Several investigations conducted by Yang et al. [1, 2], Lin et al. [3], and Qasim et al. [4] demonstrate the strong correlation between this study and the present accomplishments and difficulties in the area. The findings above highlight the importance of modern image analysis approaches, such as SIFT-assisted digital picture correlation and colour temperature modifications. These approaches are consistent with our strategy to systematically extract picture properties under different illumination situations.

The outcomes from our study support and enhance the camera technology developments mentioned by Huang in his discourse [42]. Our study focuses on the specific impact of lighting on high-resolution cameras, whereas Huang provides a comprehensive survey of the progress made in digital image processing. Given the growing need for high-quality photos in diverse fields, such as academic research and commercial photography, this feature has become crucial.

In addition, the article reproduces the practical consequences of lighting conditions on picture quality, a topic that was previously investigated by Wang et al. [8] and Genser et al. [20], Thambawita et al. [21] and Parulski et al. [22] in their separate studies on enhancing low illumination images. Our analysis reveals that lighting has a nuanced effect on the quality of a picture due to its interplay with camera properties. Camera manufacturers exert considerable effort to enhance the performance of their devices in various situations. Consequently, photographers and videographers rely on this ability to conduct timely evaluations under various lighting settings.

However, the study does have several drawbacks. While the current explanation adequately covers the functioning of high-resolution cameras, it may be improved by including more diverse lighting circumstances and camera models. The rapid progress of smartphone cameras, as emphasised by Hiapa and Danso [15] and Jiang et al. [41], enhances the importance of this expansion. It would be interesting to compare the performance of sophisticated computational photography features in modern smartphone cameras with classic high-resolution cameras in controlled laboratory settings in the future.

Furthermore, the article lays the groundwork for incorporating state-of-the-art algorithms specially tailored for image processing. Recent advancements in this field, analysed by Evsutin et al. [43] and other researchers [24, 25], provide a positive outlook on improving camera capabilities, particularly in difficult low-light situations. For instance, the progress in noise reduction methods provided by Suryanarayana et al. [8] and Yang et al. [7] and the use of convolutional neural networks to reconstruct pictures at a super-resolution of [19] Sun and Li [16] level is expected to improve the capabilities of high-resolution cameras significantly.

This article lays the groundwork for future research efforts investigating the influence of various camera characteristics on various applications. Unmanned aerial vehicle control [9], medical imaging [16], and remote sensing [28] are among the notable areas of study with great potential. Achieving more efficient and effective imaging solutions may be accomplished by understanding how individual use-case needs and camera attributes interact.

In addition, a study by Karim et al. [25] analysed the consequences of using social cloud computing to assess the quality of service, emphasising the importance of image quality in the modern day. This becomes an even more critical factor when contemplating the importance of image processing in emerging technologies like 5G [9] and its potential applications in fields like telecommunications and traffic management.

The article explores several important aspects of image processing and technology, focusing specifically on the features of high-resolution cameras and lighting situations. This aligns with existing knowledge and sets the stage for extensive future exploration and advancement. Examining the complex interactions between camera technology, image processing algorithms, and real-world application situations is crucial and shows promise.

VI. Conclusion

The investigation of camera efficiency and picture resolution yielded helpful insights into the functioning of several digital and cell phone cameras under varied settings. The article sheds light on the capabilities and limits of various cameras via a series of trials and feature extractions, allowing consumers to make educated judgements when selecting the best device for their shooting and image processing requirements.

First, the scholars examined the picture resolution of 11 digital and mobile phone cameras, capturing situations with and without a torch. The findings showed a wide variety of resolutions, with digital cameras outperforming cell phone cameras in terms of resolution. This discovery emphasises the need to know the camera's resolution while recording photographs since higher resolutions often provide more detailed and clear images.

Also looked at the preprocessing stages, which included cropping photographs to remove margins and transforming them from RGB to grayscale. The importance of preprocessing in delivering consistent and accurate findings during feature extraction was established in this paper.

The feature extraction procedure concentrated on histogram and texture characteristics, analysing factors like contrast, entropy, skewness, and kurtosis. The article on these characteristics revealed helpful information about how various cameras perform and how torch usage affects the derived data. Certain aspects were similar between cameras and flashlights, while others varied significantly.

Collecting photographs with the torch in low-resolution cameras provided predominantly medium and high-level results, but collecting images without the torch gave primarily high-level results. On the other hand, high-resolution cameras acquired photos with the torch, yielding almost high-level findings, but without the torch, the mean feature generated random values. The article also discovered several characteristics, such as entropy and kurtosis, that remained consistent, independent of resolution or torch use, making them suitable for image processing studies.

The levelling method added another degree of comprehension by categorising feature values into low, medium, and high levels. This categorisation made comparing and evaluating the information more manageable, allowing for more precise conclusions regarding the cameras' performance.

The article highlighted the importance of high-resolution cameras in current photography and image processing applications. As technology advances, most cameras today have high resolutions, making them perfect for various photographic jobs. Furthermore, in most circumstances, cell phone cameras produced equivalent results to standard cameras, making them viable choices for photography and image processing.

This article advises photographers, image processing pros, and camera enthusiasts when selecting the best camera for their unique requirements. Users may optimise their photographic experience and attain the desired picture quality by knowing the camera's resolution and features. Furthermore, the study emphasised the significance of dependable and consistent feature extraction approaches, critical in image analysis and processing jobs.

Future studies could expand on these results to investigate more sophisticated imaging capabilities and feature extraction approaches as camera technology evolves. Authors may continue improving their knowledge of camera efficiency and picture resolution by remaining up to speed on the newest camera technologies, further enabling global photographers and image processing specialists.

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