

Chapter 1

Introduction

1.1 Background and Problem Statement

In recent years, the way people obtain dermatological advice has changed significantly, mainly due to the COVID-19 pandemic. Teledermatology, a branch of telemedicine, has become increasingly popular as a method to diagnose and manage skin conditions remotely. Telemedicine involves the use of telecommunications technology to provide healthcare services from a distance, allowing patients to consult with healthcare providers without needing to be physically present.

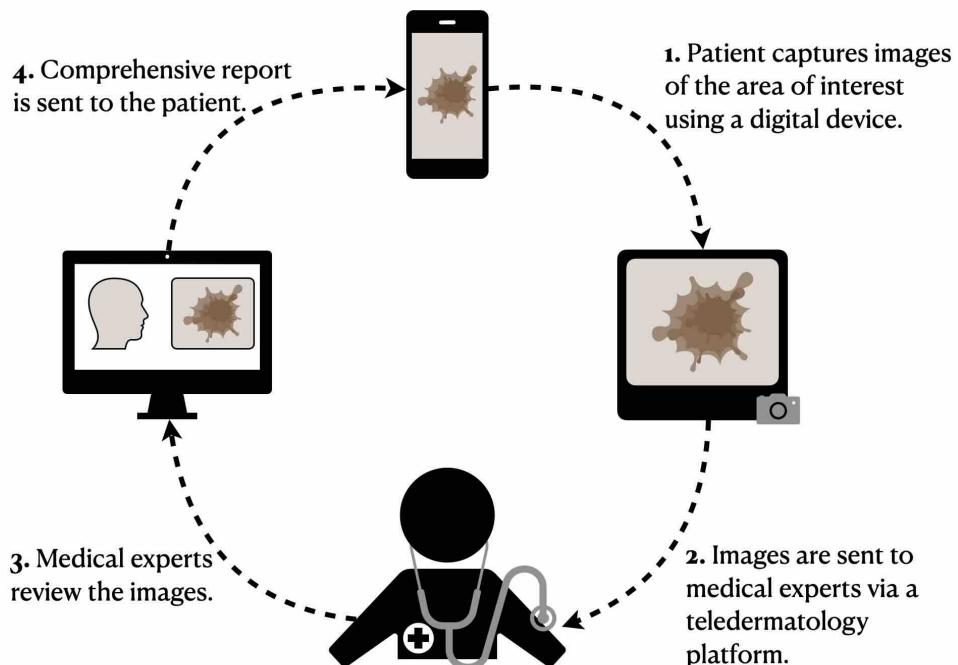


Figure 1.1: This diagram illustrates the streamlined process of a teledermatology consultation, starting from the patient capturing images of their skin condition to the receipt of a detailed medical report. Each step highlights the essential role of image quality in ensuring accurate diagnosis and effective patient care. (Created by the Author)

In teledermatology, patients use mobile applications to take pictures of their skin conditions with everyday devices like smartphones and tablets. These images are then sent to dermatologists for analysis, eliminating the need for face-to-face appointments. Figure 1.1 illustrates the streamlined process of a teledermatology consultation, starting from the patient capturing images of their skin condition to the receipt of a detailed medical report. Each step highlights the essential role of image quality in ensuring accurate diagnosis and effective patient care.

However, the success of teledermatology depends heavily on the quality of the images patients capture. Despite the convenience of modern technology, many images sent by patients do not meet the required standards. Issues such as poor lighting, blurred images, and inadequate representation of skin conditions can greatly hinder a dermatologist's ability to make accurate diagnoses. These challenges with image quality reduce the effectiveness of teledermatology.

This common problem highlights the critical need to improve the quality of images taken through mobile applications. This thesis aims to address this problem by developing and implementing automated image quality assessment techniques to enhance the reliability and effectiveness of teledermatology.

1.2 Objectives of the Thesis

The primary goal of this thesis is to develop and evaluate automated methods for assessing image quality within the context of teledermatology. The objectives are varied, starting with a comprehensive literature review of image quality assessment methods from the general imaging domain to determine their suitability for teledermatology applications. This thesis also aims to select appropriate quality metrics, apply these methods to relevant dermatological datasets, and create a reproducible repository for future research.

The specific objectives of this thesis are detailed as follows:

- An extensive review of the literature on image quality assessment (IQA) methods, focusing on their application in teledermatology.
- Identifying and selecting image quality metrics that are most suitable for assessing the quality of dermatological images.
- Evaluate the performance of selected image quality metrics on dermatological datasets to determine their effectiveness in assessing image quality.
- Develop a reproducible repository of image quality assessment tools and methodologies for teledermatology applications.

Achieving these objectives is expected to significantly enhance the efficiency and accuracy of teledermatology services by establishing a standardized approach to image quality assessment. This improvement is anticipated to streamline workflow, save time, and reduce frustration in teledermatology, providing effective tools and methodologies for evaluating the quality of patient images remotely. Ultimately, the advancements from this research will contribute to better diagnostic precision and overall patient care in remote dermatological consultations.

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1.3 Organisation of this Thesis

This thesis is structured into six chapters to provide a clear and systematic exploration of image quality assessment in teledermatology. Chapter 2 covers the literature review, discussing

previous and related works on image quality assessment (IQA) and teledermatology. Chapter 3 details the methodologies, including those used in the literature review and those specific to IQA and teledermatology. In Chapter 4, the experiments conducted are described, offering insights into the metrics used. Chapter 5 presents the results of these investigations. Finally, Chapter 6 concludes the thesis, summarizing the findings and suggesting directions for future research.

All figures and tables in this thesis are created by the author unless otherwise referenced. If any code is referenced, the path or module is provided in the footnotes.

Chapter 2

Literature Review

2.1 Image Evaluation

There are three ways to evaluate an image: assessing its quality, aesthetics, or fidelity. Each method focuses on different aspects of image evaluation and has unique applications.

Image Quality Assessment (IQA) measures the degradation of an image. This involves comparing an original, undistorted image with a processed version that has undergone changes such as compression, noise addition, or artifact introduction. The goal is to quantify how much the image quality has declined due to these changes.

Image Aesthetics Assessment focuses on the visual appeal of an image. It evaluates how pleasing an image is to the human eye, considering factors like composition, color, and overall aesthetic impact. While related to IQA, since both involve human judgment, this area is not the focus of this thesis because it deals more with subjective perceptions of beauty rather than measurable quality degradations.

Image Fidelity Assessment deals with how accurately an image represents the original scene or view. This is especially relevant in applications involving multiple views or stereo cameras, assessing the correctness of image reconstruction. However, this thesis will also not cover image fidelity assessment, as it pertains more to the accuracy of recreating an image rather than evaluating its quality after processing.

The primary focus of this thesis is on IQA, specifically looking at various types of image degradation. The following subsections will discuss common distortions, datasets that contain these distortions, and the state-of-the-art (SOTA) methods in IQA. But first, it is important to distinguish between subjective and objective quality assessment.

2.1.1 Subjective Quality Assessment

Subjective quality assessment involves human observers evaluating the quality of images based on their visual perception. This method is essential for understanding how humans perceive image quality in real-world situations, especially when technical measurements might not fully capture what people actually see and experience. There are two primary methods used in subjective quality assessment:

- Absolute Categorical Rating: In this approach, human observers are presented with a unlabeled image and asked to rate its quality based on predefined categories. Each observer evaluates the image independently, without comparing it to any reference image. This method allows evaluators to provide a direct judgment on the image's quality based on their subjective experience.
- Paired Comparison: In this method, human observers are presented with two images: a unlabeled image and a reference image. Observers then assess the quality of the test image by comparing it directly to the reference image, assigning a score based on the perceived differences in quality.

Subjective quality assessment is highly valued for its ability to accurately reflect human perception of image quality. However, this method is also resource-intensive, requiring significant time and effort from human evaluators. Additionally, subjective assessments can be influenced by variability and biases introduced by individual scorers. For example, differences in monitor color calibration, the scorer's domain knowledge, and personal preferences can affect the consistency and reliability of the evaluations. Despite these challenges, subjective quality assessment remains a critical component of comprehensive image quality evaluation, particularly in applications where the human response to an image is the ultimate measure of its quality.

2.1.2 Objective Quality Assessment

Objective quality assessment relies on mathematical algorithms rather than human judgment to evaluate image quality. This approach uses our understanding of human vision system attributes to develop mathematical equations that measure quality, even though not all methods rely on these attributes. Essentially, it involves comparing data points or features extracted from images to determine quality. This assessment is mainly categorized into three methods based on the reference data used: Full-Reference IQA (FR-IQA), Reduced-Reference IQA (RR-IQA), and No-Reference IQA (NR-IQA).



Figure 2.1: General framework of FR-IQA algorithms. Features are extracted from both images, and then the feature distance is calculated.

Full-Reference IQA (FR-IQA) involves a comprehensive comparison between a distorted image and a reference image (see Figure 2.1). Features are extracted from both images, and their differences are quantitatively analyzed to compute a quality score. While FR-IQA offers detailed assessments, it requires a reference image for every distorted image evaluated, which can limit its practicality.

Reduced-Reference IQA (RR-IQA) operates similarly to FR-IQA but does not need the complete reference image. Instead, it uses a reduced set of features extracted from both the distorted and reference images (see Figure 2.2). This method balances the exhaustive comparison of FR-IQA and the independence of NR-IQA, reducing computational demands while still providing meaningful quality assessments based on partial reference data.

Both FR-IQA and RR-IQA utilize two methods to analyze quality:

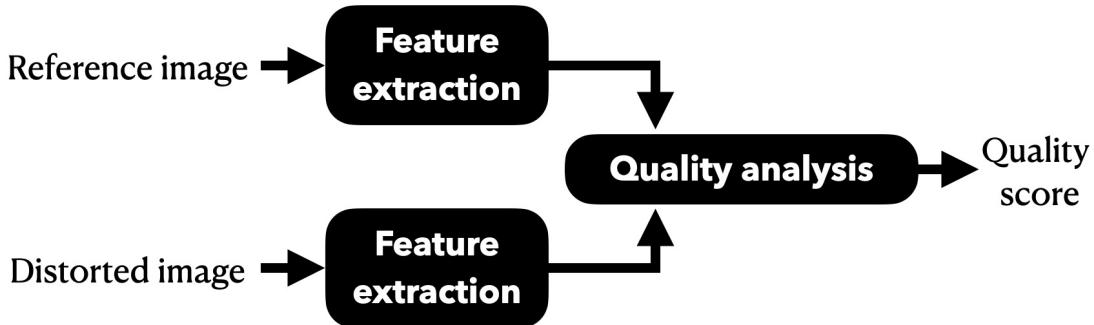


Figure 2.2: General framework of RR-IQA algorithms. Features of the reference and distorted images are extracted and used collectively to compute the quality.

- Spatial-Based Analysis: This method compares images pixel by pixel or region by region, offering straightforward interpretation and efficient computation. However, it may not fully align with how humans process images, lacking robustness in some scenarios.
- Transform-Based Analysis: This approach transforms images into a different domain (such as the frequency domain) that more closely mimics the human visual system. While robust, it is complex and computationally intensive.



Figure 2.3: General framework of no-reference image quality assessment algorithms.

No-Reference IQA (NR-IQA) does not rely on any reference image. Instead, it analyzes the distorted image alone by extracting features indicative of quality (see Figure 2.3). This method is particularly useful when no reference images are available, such as in many practical applications of teledermatology. NR-IQA can be tailored to address specific types of distortions or designed for general-purpose quality assessment, providing versatility across various domains.

For this thesis, the focus will be on No-Reference IQA because it is especially relevant for evaluating teledermatology images where reference images are usually not available. Since IQA measures distortions and NR-IQA can handle various types, it is important to identify the most common distortions encountered. The next subsection will discuss these distortions in detail.

2.1.3 Common Distortions in Image Quality Assessment

Image Quality Assessment (IQA) must address various distortions that can significantly affect the perceived quality of images. Understanding these common distortions is crucial for developing effective IQA algorithms, particularly in contexts like teledermatology, where accurate image assessment is critical. Below are the common distortions typically considered in IQA, with a reference image shown first for better comparison:

The common distortions are:

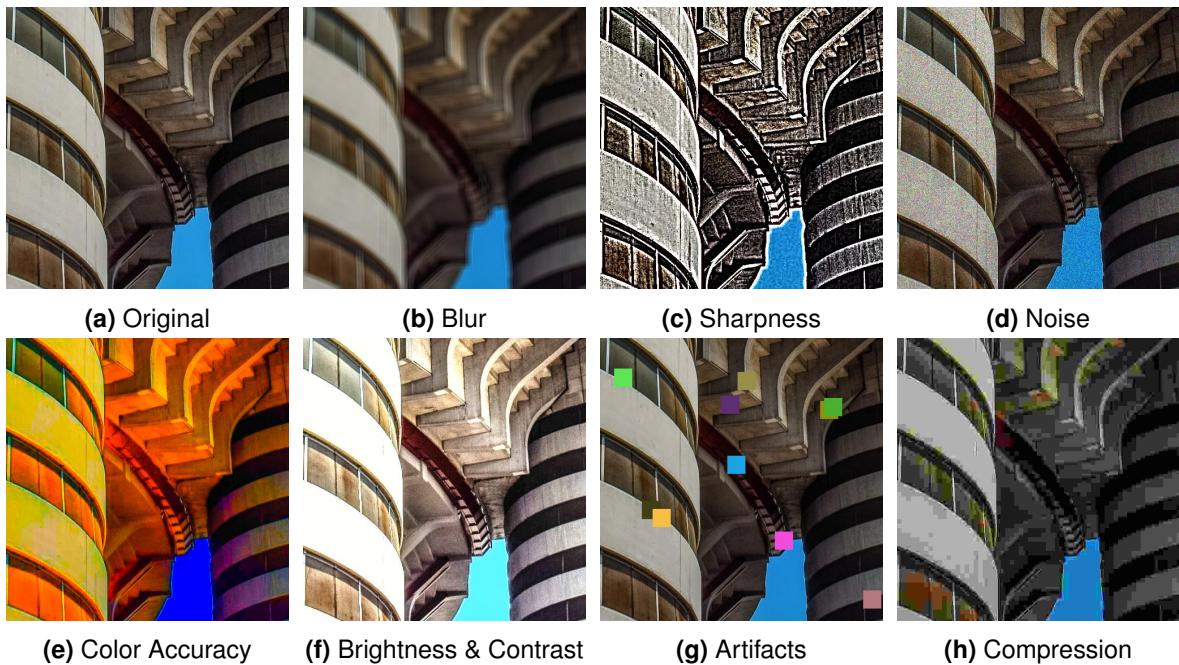


Figure 2.4: Examples of Common Distortions in Images. (adapted from (Agnolucci et al., 2023))

1. **Blur:** Blurred images lack sharpness and clarity, often resulting from motion during capturing, incorrect focus settings, or imperfections in the camera lens. See Figure 2.4b for an example of a blurred image.
2. **Sharpness:** Sharpness refers to how well-defined the edges and fine details in an image appear. High sharpness indicates clear, crisp images, while low sharpness makes an image look soft and unclear. See Figure 2.4c for an example of a sharpened image.
3. **Noise:** Noise appears as random variations in brightness or color and is often due to the limitations of the camera's sensor, particularly under low light conditions or at high ISO settings. See Figure 2.4d for an example of a noisy image.
4. **Color Accuracy:** Color accuracy refers to how faithfully colors are reproduced in an image. Distortions in color accuracy can lead to inaccurate or unrealistic color representation. See Figure 2.4e for an example of a color-distorted image.
5. **Brightness & Contrast:** Brightness is the overall light level of an image, while contrast refers to the range between its darkest and lightest areas. Proper balance of both is crucial for maintaining image visibility and detail. Excessive or insufficient brightness and contrast can make an image unusable for detailed analysis. See Figure 2.4f for an example of an image with altered brightness.
6. **Artifacts:** Artifacts are unwanted visual anomalies introduced during image acquisition or processing, such as halos, or jagged edges. See Figure 2.4g for an example of an image with artifacts.
7. **Compression:** When images are compressed to reduce file size, this often results in lost detail and visible quality degradation. See Figure 2.4h for an example of a compressed image.

Each type of distortion affects the visual quality and perceived accuracy of images, influencing the effectiveness of IQA methodologies in assessing image quality. Understanding these distortions

is essential for developing robust quality assessment algorithms and improving image clarity in various applications, including teledermatology.

2.1.4 Benchmark Datasets for IQA

Benchmark datasets play a vital role in advancing Image Quality Assessment (IQA). They provide standardized and diverse image sets with known distortions and corresponding quality annotations, helping researchers evaluate and improve IQA algorithms. These annotations, often in the form of Mean Opinion Score (MOS) and Differential Mean Opinion Score (DMOS), serve as benchmarks for algorithm performance.

Mean Opinion Score (MOS) is calculated by averaging ratings from human observers who judge the quality of images on a predefined scale. This score reflects the overall perceptual quality as seen by typical viewers and is widely used to compare the performance of different IQA methods against human visual judgment.

Differential Mean Opinion Score (DMOS), on the other hand, is derived from MOS and measures the perceived difference in quality between a reference image and a distorted version. This score is particularly useful for understanding the impact of specific distortions on image quality.

These datasets enable researchers to thoroughly test the robustness, accuracy, and generalization capabilities of different IQA methods. They also help in developing new algorithms by providing reliable quality scores, which are essential for ensuring reproducible.

An overview of IQA databases is provided in Table 2.1, and more detailed descriptions can be found in Appendix B.

2.1.5 State-of-the-Art in Image Quality Assessment

The current state-of-the-art in Image Quality Assessment (IQA) is ARNIQA (Agnolucci et al., 2023), with version 2 released on November 4, 2023. ARNIQA (leArning distoRtion maNifold for Image Quality Assessment) represents a major advancement in No-Reference Image Quality Assessment (NR-IQA). This technology aims to measure image quality based on human perception, even without a reference image. This capability is crucial in fields like teledermatology, where the quality of images directly impacts diagnostic accuracy.

Overview of ARNIQA: ARNIQA is developed using a self-supervised learning approach. It learns a comprehensive model of all possible image distortions, focusing on the types and quality of distortions rather than the content of the images themselves. This makes it highly adaptable across various domains where image content can differ significantly.

Key Features of ARNIQA:

1. **Image Degradation Model:** ARNIQA can synthetically degrade images through up to 1.9 billion distinct degradation patterns. This model can apply up to seven different types of distortions in one sequence, covering a wide range of real-world scenarios. Training with such diverse distortions ensures that ARNIQA can accurately assess image quality across various conditions and avoid the need for large labeled datasets.
2. **SimCLR Framework:** At the core of ARNIQA is the SimCLR (Simple Framework for Contrastive Learning) framework. This framework enables the model to learn meaningful representations of image quality by comparing different versions of the same image and focusing on their similarities and differences. SimCLR constructs positive pairs by applying

Table 2.1: An overview of IQA databases

Category	Database	Year	#Ref.	#Dist.	#Dist. Type	#Dist. Level	Resolution Type	Ground-truth
General	LIVE	2004	30	779	JPEG, JP2K, WN, GB, FF	5 or 4	768 × 512	DMOS
	TID2008	2008	25	1700	17 ^a	4	512 × 384	MOS
	TID2013	2013	25	3000	24 ^b	5	512 × 384	MOS
	CSIQ	2009	30	866	JPEG, JP2K, WN, GB, APGN, GCD	5 or 4	512 × 512	DMOS
	A57	2007	3	54	DWT, AGWN, JPEG, JP2K, JP2K-DCQ, GB	3	512 × 512	MOS
	WED	2017	4744	94880	JPEG, JP2K, GB, WN	5	-	-
	KADID-10k	2019	81	10125	25 ^c	5	512 × 384	DMOS
Multiple Dist.	KADIS-700k	2020	140000	700000	25 ^d	5	512 × 384	DMOS
	LIVEMD	2012	15	405	GB followed by JPEG, GB followed by WN	-	1280 × 720	DMOS
	MDID2013	2013	12	324	corrupted successively by GB, WN, and JPEG	-	768 × 512 or 1280 × 720	DMOS
	MDID2016	2016	20	1600	GB or CC first, JPEG or JP2K second and WN last	-	512 × 384	MOS
Screen content	SIQAD	2014	20	980	WN, GB, CC, JPEG, JP2K, MB, LSBC	7	700 × 700	DMOS
	SCIQ	2017	40	1800	WN, GB, MB, CC, JPEG, JP2K, CSC, CQD	5	1280 × 720	MOS
	CCT	2017	72	1320	HEVC and HEVC-SCC coding	11	1280 × 720 to 1920 × 1080	MOS
	HSNID	2019	20	600	WN, GB, MB, CC, JPEG, JP2K	5	-	MOS
Authentic Dist.	LIVE Wild	2016	0	1162	-	-	500 × 500	MOS
	CID2013	2015	0	480	-	-	1600 × 1200	MOS

Note: #Ref.: Total number of pristine images. #Dist.: Total number of distorted images. AGWN: Additive Gaussian white noise. WN: White noise.

APGN: Additive pink Gaussian noise. CC: Contrast change. CSC: Color saturation change. CQD: Color quantization with dithering.

DWT: Quantization of the LH subbands of a 5-level DWT. FF: Simulated fast fading Rayleigh channel. GB: Gaussian blur. MB: Motion blur.

GCD: Global contrast decrements. HEVC-SCC: Screen content coding extension of high efficiency video coding. JPEG: JPEG compression.

JP2K: JPEG2000 compression. JP2K-DCQ: JPEG-2000 compression with DCQ. LSBC: Layer segmentation based compression.

^aSee detailed types on database page: <https://www.ponomarenko.info/tid2008.htm>

^bSee detailed types on database page: <https://www.ponomarenko.info/tid2013.htm>

^cSee detailed types on database page: <https://database.mmsp-kn.de/kadid-10k-database.html>

^dSee detailed types on database page: <https://database.mmsp-kn.de/kadid-10k-database.html>

the same distortion settings to two different images, ensuring that the model concentrates on the distortions rather than the content. To further enhance the model's discriminative capability, SimCLR introduces subtle variations by downsampling images before cropping and applying distortions, creating hard negative examples. These examples help the model differentiate between similar-looking images with different types of degradation. By using this approach, the SimCLR framework ensures that ARNIQA effectively learns to recognize and assess various distortions, enhancing its ability to provide accurate image quality

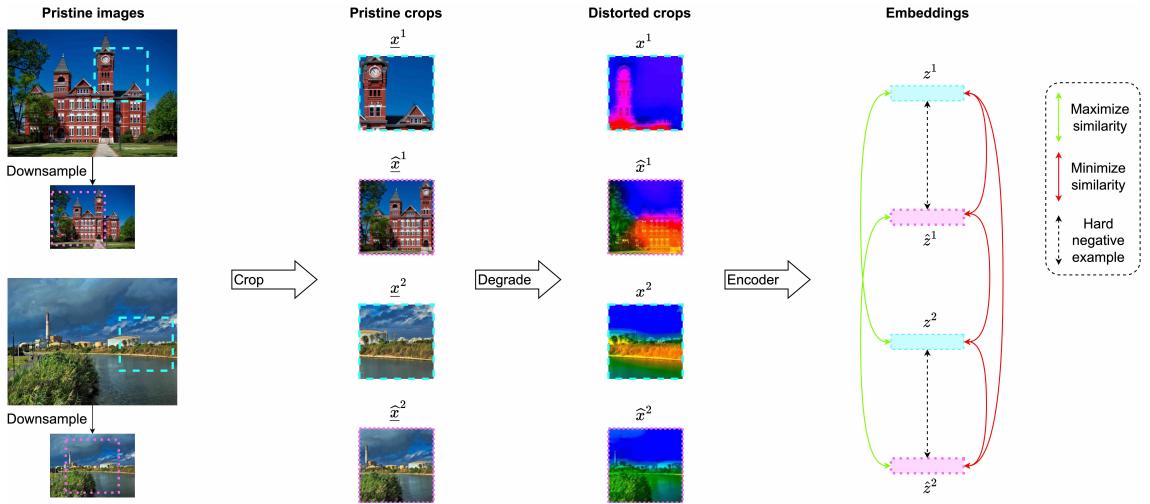


Figure 2.5: Overview of the training strategy for ARNIQA. Two pristine images are cropped and equally degraded. The model maximizes the similarity of their embeddings while minimizing the similarity to embeddings from degraded crops of half-scale versions of the original images. This process creates hard negative examples by introducing downsample distortion, demonstrating how original and half-scale degraded crops differ despite identical degradation. (Agnolucci et al., 2023).

assessments (see Figure 2.5).

3. Linear Regressor: A Linear Regressor maps the features learned by SimCLR to quality score ranging from 0 to 1. This score reflects the relative quality of the image based on the distortions present.

Training Strategy of ARNIQA: ARNIQA's training strategy involves two main phases:

1. Encoder Pre-training: The model is first trained on a large set of unlabeled images that are synthetically degraded. This helps the encoder learn features related to different types and levels of image degradation.
2. Regressor Training: In the second phase, a specific regressor is trained using the Mean Opinion Scores (MOS) of images. This step translates the learned features into actual quality scores.

Advantages of ARNIQA: ARNIQA achieves high performance with only up to 0.5% of the data required by other methods, thanks to its focus on distortion patterns rather than image content. It provides reliable and consistent quality assessments across a wide range of distortions and severities, demonstrating its robustness. Additionally, ARNIQA is particularly suitable for tele-dermatology as it can handle varying image quality resulting from different lighting conditions, camera quality, and patient handling.

2.1.6 Challenges and Opportunities in Image Quality Assessment

One major challenge in IQA is that assessing image quality can be very subjective. Different people can have different opinions on what looks good or bad, making it hard to create standard measures. This is especially important in teledermatology, where the quality of images directly affects medical diagnoses. Another challenge is that images can have many types of problems,

like blurring, noise, compression artifacts, and color issues. Each problem affects the image in a different way, and it's tough to develop IQA methods that can handle all these issues accurately. Additionally, in many real-world applications, including teledermatology, we often don't have high-quality reference images to compare against. This makes it difficult to evaluate the quality of distorted images. Therefore, developing methods that don't need reference images (No-Reference IQA) is essential.

A big opportunity in IQA is the advancement of self-supervised learning techniques. These methods, like those used in ARNIQA, allow models to learn from large amounts of data without needing a lot of labeled examples. This approach saves time and money because it reduces the need for manually labeled data. It also makes it possible to develop high-quality IQA models that can work well even without reference images.

By addressing these challenges and leveraging the opportunities, we can significantly improve how we assess image quality.

2.2 Teledermatology

This section covers teledermatology and highlights the importance of image quality in remote skin assessments. We will start by explaining what teledermatology is and then discuss why having high-quality images is crucial for accurate diagnoses and treatment.

We'll also look at the quality standards needed for teledermatology images and review public datasets available for research. Next, we'll briefly examine different methods used to assess image quality in teledermatology, based on previous studies. Finally, we'll explore the challenges and opportunities in the field, focusing on how to improve image quality assessment. This approach will help us understand the current state of teledermatology and find ways to enhance it.

2.2.1 Introduction to Teledermatology

Teledermatology is a branch of telemedicine that allows dermatologists to provide remote consultations and treatment using telecommunications technology. This is especially helpful for patients in remote areas, ensuring they get timely and effective skin care. There are two main methods used in teledermatology: real-time (synchronous) and store-and-forward (asynchronous).

Real-time teledermatology involves live video consultations between the dermatologist and the patient. This allows for immediate interaction and feedback, making it useful for urgent cases. However, it requires both the patient and the dermatologist to be available at the same time, which can be a limitation.

Store-and-forward teledermatology involves sending medical information, including images and patient history, to dermatologists who review it later. This method offers more flexibility since it doesn't require the patient and dermatologist to be available simultaneously (Jiang et al., 2022). Figure 1.1 shows the process of a teledermatology consultation, from the patient taking pictures of their skin condition to receiving a detailed medical report. Each step highlights the importance of image quality for accurate diagnosis and effective patient care.

High-quality images are crucial in teledermatology because they directly impact the accuracy of remote diagnoses. Poor image quality can lead to incorrect diagnoses or delayed treatment, reducing the benefits of teledermatology. Therefore, ensuring that images meet specific quality standards is essential for successful teledermatology services.

2.2.2 Quality Criteria for Teledermatology Images

High-quality images are crucial in teledermatology to ensure accurate diagnoses and effective patient care. The International Skin Imaging Collaboration (ISIC) has set guidelines for standardizing images. Out of nine recommended criteria, we will focus on seven key criteria that directly impact image quality. The other two, "Scale and Measurement" and "Image Storage," are not relevant because they are not directly related to image quality in teledermatology. "Scale and Measurement" is less important in this context, and "Image Storage" deals more with regulations than with image quality (Finnane et al., 2017).

Here are the seven key criteria for teledermatology images, illustrated in Figure 2.6, along with recommendations on how to meet each criteria:

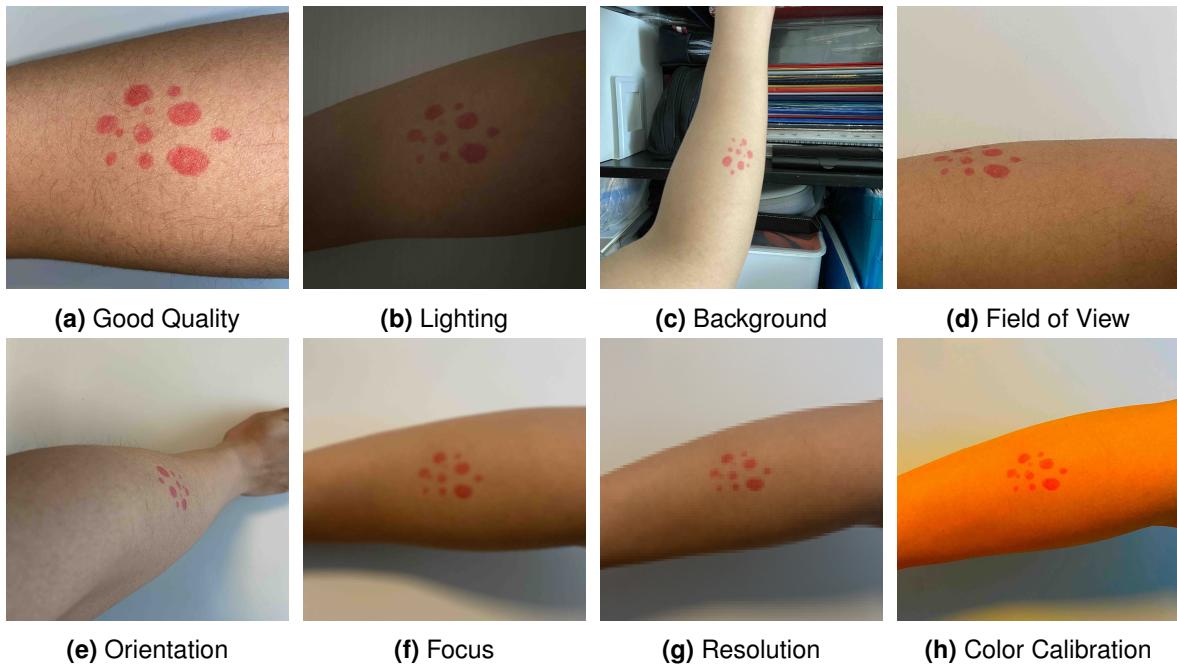


Figure 2.6: Examples of teledermatology images showing good quality, poor lighting, distracting background, improper field of view, incorrect orientation, lack of focus, low resolution, and poor color calibration.

1. **Lighting:** Good lighting is essential. It should be even and not too harsh, avoiding shadows or bright spots that can hide details. *Use natural light or soft artificial light to clearly show the skin lesion.*
2. **Background:** The background should be plain and uncluttered to keep the focus on the skin issue. A simple, non-reflective background like white or gray works best. *Use a plain, non-reflective background to minimize distractions and keep the focus on the skin lesion.*
3. **Field of View:** The image should include the entire lesion and some surrounding skin. This helps provide context for a more accurate diagnosis. *Make sure the lesion is centered and fully visible in the frame.*
4. **Orientation:** The image should be taken from the correct angle to match standard anatomical positions. This helps the dermatologist understand where the lesion is on the body. *Keep the camera straight and aligned with the lesion.*
5. **Focus & Depth of Field:** The image should be in sharp focus, with the entire lesion clear and detailed. Adjust the camera settings to ensure the lesion is not blurry. *Ensure the camera is in focus and adjust the aperture to achieve sufficient depth of field.*
6. **Resolution:** High resolution is important to show fine details. Use a camera with good resolution settings to capture clear and detailed images of the skin. *Adjust the camera settings to the highest resolution possible to ensure clarity and precision in the image.*
7. **Color Calibration:** Accurate colors are necessary to assess the skin lesion correctly. Make sure the colors in the image match real life. *Use a color reference chart or adjust the white balance settings on the camera to ensure accurate color reproduction.*

By following these guidelines, teledermatology practitioners can ensure their images are of high quality, leading to better diagnoses and patient care.

2.2.3 Teledermatology Datasets

In teledermatology, having high-quality image datasets is crucial for developing and testing methods to assess image quality. While many datasets exist for dermatology, they are not always designed specifically for teledermatology. The main difference is that dermatology datasets often include more professional images taken in clinical settings, including close-up dermoscopic images which provide detailed views of the skin.

Here are seven public datasets that can be used for teledermatology:

- **ACNE04:** This dataset focuses on acne severity and lesion counting, containing 1,457 images with detailed annotations for training and testing purposes (Wu et al., 2019).
- **DDI:** Provides 656 high-quality images curated by dermatologists for detailed skin tone evaluation and diagnostic accuracy (Daneshjou et al., 2022).
- **Derm7pt:** Utilizes 1,011 lesion cases to train a neural network for classifying skin lesions and melanoma using the 7-point checklist (Kawahara et al., 2019).
- **Fitzpatrick17k:** Includes 16,577 images annotated for Fitzpatrick skin type across 114 different skin conditions (Groh et al., 2021).
- **Monkeypox Dataset 2022:** Contains approximately 1,905 images focused on monkeypox, useful for developing diagnostic tools (Ahsan et al., 2022).
- **PAD-UFES-20:** Comprises 2,298 clinical images from smartphones, enriched with clinical metadata for comprehensive research (Pacheco & Krohling, 2020).
- **SCIN:** Emerged from a crowdsourcing initiative, this dataset contains 10,408 images capturing a broad spectrum of dermatological conditions (Ward et al., 2024).

These datasets provide valuable images and annotations that help develop and test image quality assessment methods for teledermatology.

2.2.4 Related Work on Image Quality Assessment in Teledermatology

In teledermatology, two key methods for detecting image quality have been highlighted in previous studies: TruelImage (Vodrahalli et al., 2020) and ImageQX (Jalaboi et al., 2023). Both methods work closely with dermatologists to ensure their models understand what is needed for accurate diagnoses.

TruelImage (A Machine Learning Algorithm to Improve the Quality of Telehealth Photos), introduced in 2021, uses an automated machine learning system to detect poor-quality dermatology photos and help patients take better images. This method was developed because many low-quality images submitted by patients disrupt the clinical workflow. TruelImage uses a semantic segmentation algorithm to identify skin areas, then generates features and classifies the quality. It focuses on common issues like blur, poor lighting, and zoom problems. TruelImage is efficient enough to run on older smartphones and is easy to understand, making it reliable across different skin tones. It was trained on a diverse dataset, including images from Google Images and Stanford Health Care. However, it has limitations: it cannot handle cases where only the background is blurry or poorly lit, it cannot detect framing issues, and it cannot discard images that do not contain skin (Vodrahalli et al., 2020).

Released in January 2023, **ImageQX** (Explainable Image Quality Assessments in Teledermatological Photography) is a convolutional neural network that automatically assesses the quality of

dermatology images. It focuses on issues like bad framing, poor lighting, blur, low resolution, and distance problems. ImageQX was trained on 26,635 photos and validated on 9,874 photos, each annotated by up to 12 board-certified dermatologists. Its main innovation is providing explanations for poor quality, guiding patients on how to take better images. ImageQX is lightweight, only 15 MB, and can be easily used on mobile devices. It achieves a macro F1-score of 0.73, showing its effectiveness in real-world applications. However, it has limitations in handling certain quality issues, like explaining blurry images, and relies heavily on dermatologist-annotated images, highlighting the need for a diverse and high-quality training dataset (Jalaboi et al., 2023).

Both ImageQX and TruelImage make significant contributions to automated image quality assessment in teledermatology. They both address common issues like blur and poor lighting. ImageQX excels in providing detailed feedback on how to improve image quality, while TruelImage focuses on being computationally efficient and interpretable, making it suitable for older smartphones. From these methods, we learn the importance of lightweight models, providing actionable feedback to users, and using a diverse training dataset to ensure robustness. However, there is still room for improvement in handling complex lighting conditions and ensuring accurate zoom detection.

2.2.5 Challenges and Opportunities in Image Quality Assessment for Teledermatology

Teledermatology faces several challenges similar to those in Subsection 2.1.6. A major issue is the subjectivity of image quality assessment. Different dermatologists might have different opinions on what makes a good image, making standardization difficult. This variability can affect the accuracy of medical diagnoses since the quality of images is crucial. Common problems in teledermatology images include blurring, poor lighting, compression artifacts, and color issues. Each problem affects the image differently, making it hard to develop methods that handle all these issues well. Additionally, high-quality reference images are often unavailable, making it tough to evaluate the quality of patient-taken images accurately. Patients also use various devices and capture images under different conditions, adding to the complexity.

Despite these challenges, there are significant opportunities to improve teledermatology. Collaboration with dermatologists, as seen in methods like ImageQX and TruelImage, can improve IQA models by ensuring they meet the needs of medical professionals. These models can provide real-time, actionable feedback to patients on how to take better images, improving the quality of images submitted for remote consultations.

Chapter 3

Methodology

Based on the insights from Chapter 2, this chapter provides an overview of the key ideas and concepts needed to achieve the research goals. The following sections will explore important concepts related to image quality assessment in teledermatology and explain the reasoning behind this work. Detailed implementation of these steps will be covered in Chapter 4.

3.1 Explorative Approach

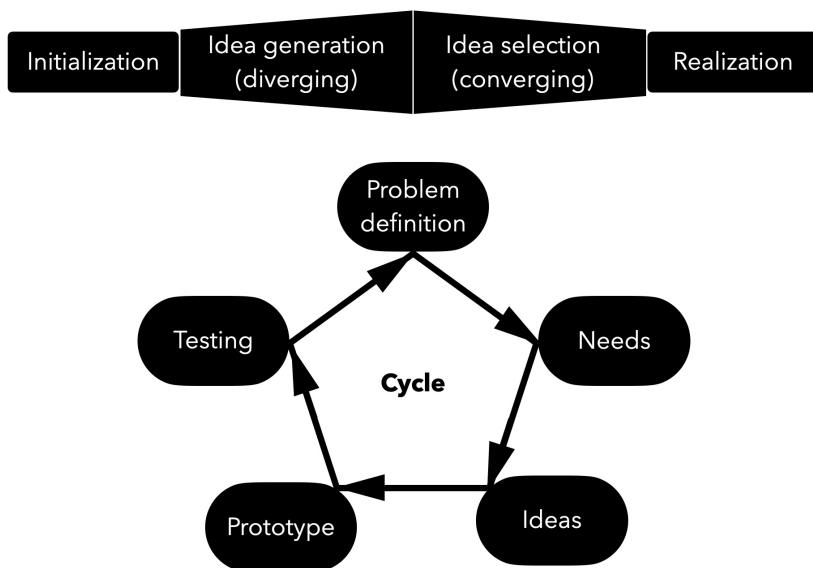


Figure 3.1: Illustration of the explorative approach, including the stages of initialization, idea generation, idea selection, and implementation. The lower part of the figure shows the decision cycles (Hoffmann et al., 2016).

Teledermatology, especially when focused on Image Quality Assessment (IQA), offers many opportunities for innovation due to the different types of image distortions and ways to address them. To handle this complexity, an exploratory approach was used in this research. This approach is flexible and innovative, allowing for adjustments as new information is discovered, unlike traditional methods like the waterfall approach.

At the beginning, the problem was broadly defined, allowing for a flexible and adaptive approach. The research progressed through creative problem-solving with multiple learning cycles, refining ideas and methods iteratively. The project was divided into two main phases. In the *Diverging Phase*, the research question's scope was expanded to generate new ideas continuously, based on insights from the ongoing literature review. In the *Converging Phase*, the focus on combining these ideas into clear findings and conclusions, aiming to create a unified understanding of the initial problem. This exploratory model is shown in Figure 3.1, which illustrates the stages of starting, generating ideas, selecting ideas, and implementation, along with the decision cycles (Hoffmann et al., 2016).

3.2 Project Control

Even with an exploratory approach, it is important to have a rough timeline to guide the research tasks. A workflow was established before starting, detailed in the planning document attached to this thesis.

There are three key milestones identified in the first half of the project, each crucial for its success:

Understanding Teledermatology: Gaining a thorough understanding of the field to ensure all subsequent actions are relevant and well-informed.

State of the Art in IQA: Identifying the latest developments in IQA to ensure the methods used are up-to-date and effective.

Availability of Teledermatology Data: Securing access to appropriate datasets for conducting meaningful IQA.

These milestones are essential because each phase of the project relies on the successful completion of the previous one. Missing any of these milestones could significantly impact the project and might require a fundamental reassessment of the objectives outlined in Section 1.2.

3.3 Research Steps

As mentioned, this study was exploratory, so it was not possible to follow a strict, step-by-step process. However, for the individual key steps, I took a systematic approach to stay organized and ensure that each step was done in the right order:

3.3.1 Literature Review

First, I began by getting an overview of my research field. As I was new to the domain of teledermatology and dermatology, this initial step was crucial. By researching and reading relevant literature, I gradually built a solid understanding of the field. Next, I identified the core topics related to my research objectives. Once I had these key topics, I carefully selected the databases to search, focusing on those most relevant to my field: PubMed¹, Google Scholar², IEEE Xplore³, Connected Papers⁴, and Papers with Code⁵. Using these databases, I applied search filters to narrow down the results, such as limiting the search to articles published after 2020.

¹<https://pubmed.ncbi.nlm.nih.gov>

²<https://scholar.google.com>

³<https://ieeexplore.ieee.org/Xplore/home.jsp>

⁴<https://www.connectedpapers.com>

⁵<https://paperswithcode.com>

I reviewed the titles of the search results and opened the ones that seemed interesting. After that, I read the abstracts to determine their relevance. Depending on the relevance of the abstract and some of the figures, I decided whether to read the full paper. Additionally, for state-of-the-art methods, I focused on finding and reading papers that had published their code and model weights if models were trained. This systematic approach ensured that my literature review was thorough and focused on the most relevant and up-to-date research.

3.3.2 Data Collection and Preparation

In searching for a suitable dataset to evaluate image quality in teledermatology, a major challenge was the lack of Mean Opinion Score (MOS) or Differential Mean Opinion Score (DMOS) in teledermatology datasets, as commonly found in traditional IQA datasets mentioned in Subsection 2.1.4. This scarcity is due to the resource-intensive nature of labeling images in the medical field.

To address this gap, I created a distortion pipeline that synthetically distorts images based on the seven criteria defined in Subsection 2.2.2. Each type of distortion has five levels of severity, with the severity indicating how poor the image quality is. These distortions are carefully selected to simulate real-world imperfections commonly encountered in teledermatology. Each image is then labeled according to the severity and type of distortion applied, creating a dataset that not only includes the distorted images but also features precise annotations regarding their quality. This allowed me to artificially create labels for my images. For this, I needed high-quality images to start with. I chose two datasets: the SCIN dataset for its relevance and uniqueness, and the Fitzpatrick17k dataset to complement the SCIN dataset.

Unlike many dermatology datasets that mainly focus on skin cancer diagnostics by classifying malignant and benign tumors, the SCIN dataset covers a broader range of common dermatological conditions, including allergic, inflammatory, and infectious diseases. These conditions are frequently encountered in everyday clinical practice but are underrepresented in existing datasets. The SCIN dataset is particularly valuable because it captures images of early-stage conditions. Over half of the images were taken less than a week from the onset of symptoms, with 30% captured less than a day after symptoms appeared (Ward et al., 2024). These are conditions patients are likely to consult via teledermatology platforms before visiting traditional healthcare settings. The Fitzpatrick17k dataset contains more clinical setting images, which provide good quality but do not represent the variability seen in typical teledermatology images (Groh et al., 2021), so I used the Fitzpatrick17k dataset only for training purposes. In total, I filtered 475 good quality images from the Fitzpatrick17k dataset and another 475 good quality images from the SCIN dataset, along with 200 randomly selected test images from the SCIN dataset.

This approach to dataset preparation not only tailored the data to the specific needs of this research but also established a framework for systematically assessing image quality in teledermatology. This preparation is crucial for the next phases of the project, which involve training and validating the image quality assessment model to ensure it can reliably perform in real-world teledermatology applications.

3.3.3 Feature Extraction

Feature extraction is the next important step where the SimCLR model from ARNIQA is used to identify key features from the distorted images. These features capture the patterns of distortions that affect image quality. The extracted features and the generated labels are then used to train different models, including XGBoost regressor, XGBoost classifier, and MLP regressor, to see which one works best for assessing image quality.

3.3.4 Training and Validation

The training of the models is based on the prepared training data. Since I am generating labels and distorted images, I am not restricted by the original amount of data. I can run the images through the distortion pipeline multiple times, creating various versions of distortions from the original images. The models are then trained with these data to develop their ability to assess image quality. Validation is done in parallel with training by using a portion of the data as a validation set. This helps evaluate and monitor the performance of the models.

3.3.5 Testing and Experiments

After completing the training, the models are evaluated using independent test data. I labeled 200 test images, scoring each one on the seven quality criteria to ensure the model's performance can be compared to human evaluation. This phase is crucial to assess the actual performance and reliability of the models. The evaluation is conducted using defined metrics such as Precision, Recall, Spearman's Rank Order Correlation Coefficient (SROCC), and Pearson Linear Correlation Coefficient (PLCC). The results of this evaluation provide valuable insights into the strengths and weaknesses of the image quality assessment models and serve as a basis for further improvements or adjustments.

3.3.6 Discussion and Further Development

In conclusion, the results of the project are analyzed and discussed. This discussion includes an evaluation of the achieved goals, an analysis of the challenges and limitations of the project, and a look at possible further developments. Additionally, potential applications of the developed image quality assessment models in teledermatology are considered, along with the opportunities and challenges that arise from these applications.

Chapter 4

Implementation

This chapter delves into the detailed implementation of the methodologies outlined in Chapter 3, focusing on the specific processes, experiments, and analyses conducted. It includes the practical steps taken to prepare data, apply distortions, extract features, and train the regression model to assess image quality in teledermatology.

4.1 Image Selection and Labeling Process

This section describes the initial stages of the implementation, focusing on the selection and preparation of the image datasets used in the study.

4.1.1 Image Filtering and Selection

The first step in preparing the images involves carefully choosing high-quality pictures from the SCIN dataset, which mainly includes pictures of early-stage dermatological conditions. This selection is done manually as it ensures that each image is clear and useful for clinical use. The primary focus during selection is for images that are well-framed and free of any distortions that might affect their usefulness in diagnosis.

Each selected image is checked to make sure it doesn't have any blurring that might hide important details of the skin condition, as clear images are crucial for accurate diagnosis. Additionally, it's important that the images are properly lit and show true contrast, this means they shouldn't be too bright or too dark. Proper lighting and contrast help in accurately showing the skin's condition. Lastly, the images must represent realistic skin tones and colors. Accurate color representation is critical because wrong colors can lead to incorrect diagnoses. This careful selection process of images ensures that the baseline images used for further distortion and analysis are of good quality, providing a solid foundation for the subsequent experimental stages.

4.1.2 Labeling of the Test Set

The labeling process involves manually scoring approximately 50 high-quality images and 200 images with various distortions. These images are evaluated based on seven key quality criteria crucial for teledermatology: lighting, focus, orientation, color calibration, background, resolution, and field of view. Each image is scored on a scale from 0 to 1 for each criterion, where 0 indicates no distortion and 1 indicates extreme distortion.

This manual labeling is facilitated through a custom Python script, which displays each image and prompts the user to enter scores for each distortion criterion. The scores are collected in a structured format and stored in a JSON file for subsequent analysis. This structured and meticulous approach ensures that each image is evaluated consistently and comprehensively.

Visualization of Label Distribution

To understand the distribution of labels and how frequently distortions occur across different criteria, histograms are generated. These histograms are particularly useful for visualizing the prevalence and severity of distortions in the dataset. Two histograms are plotted for each criterion:

The first histogram shows the distribution of images scored as '0' for a specific criterion, representing images where no distortion is observed.

The second histogram displays the distribution for images where a distortion is present (scores >0), showing the varying levels of distortion severity.

These histograms provide valuable insights into the commonality and impact of each type of distortion, aiding in the analysis of how distortions affect overall image quality. They also highlight the criteria that may require more focused attention during the model training and validation process.

4.2 Distortion Pipeline

The distortion pipeline is central to simulating realistic image quality issues. Each quality criterion has multiple types of distortions, each having five ranges of intensity, increasing in severity. All distortion types begin at zero, indicating no distortion applied, and progress to higher values that represent increasing levels of the specified distortion. Visual representations of the types of degradations at different ranges for each quality criterion is provided in the Appendix A.

This section describes each distortion type and its impact on image quality, highlighting the adaptability of the pipeline in generating training images that reflect a range of realistic conditions.

4.2.1 Distortion Types

Here, each distortion type is briefly described, highlighting how they simulate different aspects of image degradation:

1. Lighting:

- *Brighten*: applies a sequence of color space transformations, curve adjustments, and blending operations to enhance the brightness of an input image, resulting in an output image with increased visual intensity;
- *Darken*: similar to brighten operation, but it leads to a decreased visual intensity;

2. Focus:

- *Gaussian blur*: filters every pixel of the image with a simple Gaussian kernel.
- *Lens blur*: filters every pixel of the image with a circular kernel;
- *Motion blur*: filters every pixel of the image with a linear motion blur kernel to simulate the effect of a moving camera or a moving object in the scene. Consequently, the image appears blurred in the direction of the motion;

Histogram:
 "Distribution of images scored as 0 for the focus criterion, indicating no distortion." or "Distribution of scores for the focus criterion where distortion is present, illustrating the range and frequency of severity."

3. Orientation:

- *Top perspective*: temp;
- *Bottom perspective*: temp;
- *Left perspective*: temp;
- *Right perspective*: temp;

4. Color calibration:

- *Color saturation 1*: converts the image to the HSV-color space and then multiplies the saturation channel by a factor;
- *Color saturation 2*: converts the image to the LAB-color space, then multiply each color channel by a factor;

5. Background:

- *temp*: temp;

6. Resolution:

- *temp*: temp;

7. Field of view:

- *temp*: temp;

4.3 Distortion Implementation Process

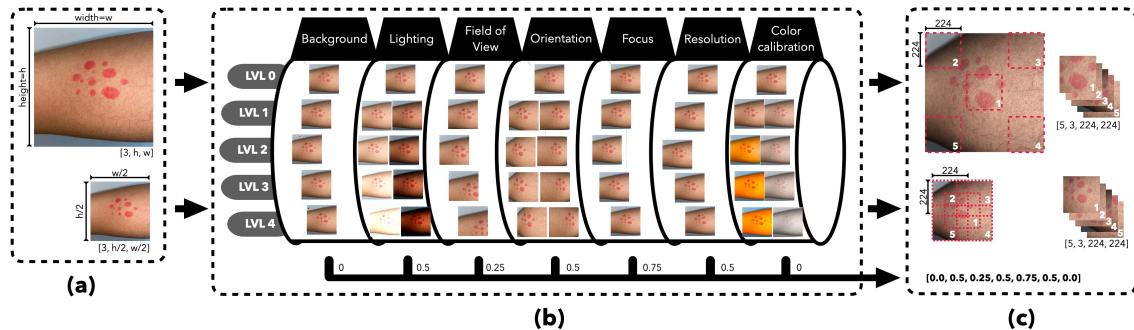


Figure 4.1: Distortion pipeline for generating training images with varying levels of distortion.

The good quality images selected from the SCIN (Ward et al., 2024) dataset are processed, where each image is first resized to a target resolution of 512 pixels while maintaining the aspect ratio. This resizing is crucial to standardize the input size and improve the consistency of feature extraction across different images. For each image, a downsampled version is created. The downsampled image serves as a means to generate hard negative examples, enhancing the learning process.

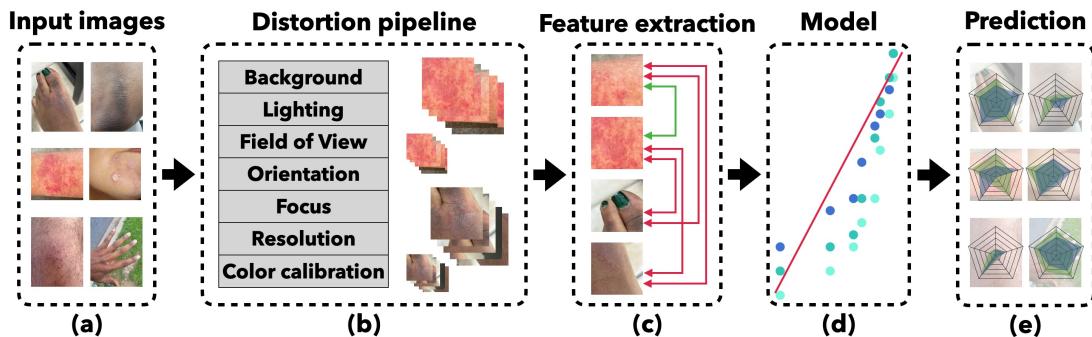
The images then undergo a series of distortions through a defined pipeline, as mentioned in Section 4.2, which applies a sequence of distortion functions. These functions are chosen based on a Gaussian distribution with a mean of 0 and a standard deviation of 2.5, ensuring a probabilistic variation and to add a realistic randomness in the severity of applied distortions. The distortion values are mapped to a uniform scale from 0 to 1, representing the intensity of the distortion from none to extreme. This mapping is crucial for training the model to recognize and quantify these distortions accurately.

Table 4.1: Mapping of numerical values to levels of distortion.

0	0.25	0.5	0.75	1
No distortion applied	Slight distortion	Moderate distortion	Significant distortion	Extreme distortion

After the distortions are applied, both the original and downsampled images are processed to extract smaller crops from significant areas such as the center and the four corners. This step is vital as it ensures that the model learns from various perspectives within the same image, enhancing the robustness of the learned features. The crops are then stacked to form a batch of images ready for feature extraction. But first, the images are normalized using standard values (mean=[0.485, 0.456, 0.406], std=[0.229, 0.224, 0.225]) to match the input requirements of the neural network used in SimCLR. This normalization helps in stabilizing the training process by scaling the input features to a common range.

The prepared images are then passed through the SimCLR network to extract features. The network maximizes the similarity of embeddings from images degraded in a similar manner while maximizing the dissimilarity with embeddings from different images or from downsampled versions, which serve as hard negative examples.

**Figure 4.2:** Architecture.

4.4 Feature Extraction with SimCLR

Once the crops from the distorted and downsampled images have been generated, they are processed through the SimCLR framework implemented within the ARNIQA system to extract meaningful features. SimCLR, a pivotal component of ARNIQA, operates based on a self-supervised contrastive learning approach. This framework is adept at maximizing the similarity of features between images that have been distorted in a similar manner, regardless of their initial content.

The implementation of the SimCLR framework from ARNIQA forms a pivotal part of the feature extraction process for this project. SimCLR stands out due to its robust self-supervised learning capabilities, particularly suited for handling the complex distortions applied to the images in this study.

Overview of SimCLR in ARNIQA:

SimCLR operates by maximizing the similarity between embeddings of differently cropped images from the same source but subjected to identical distortions, while also minimizing their similarity to embeddings from differently distorted crops. This methodology effectively trains the model to recognize and quantify similar degradation patterns across diverse image content, leveraging a contrastive loss function that is critical for learning detailed distortion characteristics.

Using the mean and std of Imagenet is a common practice. They are calculated based on millions of images. If you want to train from scratch on your own dataset, you can calculate the new mean and std. Otherwise, using the Imagenet pretrianed model with its own mean and std is recommended.

Training Strategy with SimCLR:

The training strategy involves processing pairs of images through a series of steps:

Image Pair Selection: Two pristine images are selected randomly from the dataset. **Distortion Application:** Each image is cropped and subjected to the same distortion, based on predefined distortion compositions. **Embedding Comparison:** The embeddings of the distorted image crops are compared to ensure that similar distortions produce similar embeddings. This process is visualized in Figure 3 from the ARNIQA paper, which illustrates how the embeddings of similarly degraded image crops are aligned, while those of differently degraded crops serve as hard negative examples. This setup is crucial for training the model to discriminate subtle differences in degradation, enhancing its sensitivity to variations in image quality.

Hard Negative Examples:

To enhance the model's ability to discern subtle degradation differences, images are also down-scaled before cropping and distorting, creating hard negative examples. These examples are crucial for training because they share similar content but differ in distortion due to the downsampling process, challenging the model to fine-tune its discrimination capabilities.

Reproducibility and Practical Implementation:

The availability of code and weights for the SimCLR implementation in ARNIQA ensures that this methodology is not only reproducible but also accessible for future research. This open access to resources supports ongoing improvements and adaptations in the field, fostering further developments in image quality assessment for teledermatology.

Benefits of SimCLR in Image Quality Assessment:**Utilizing SimCLR provides significant advantages:**

Unlabeled Data Usage: It can effectively learn from unlabeled data, which is particularly beneficial in scenarios where high-quality labeled datasets are scarce. **Robust Feature Extraction:** By learning to identify and differentiate between various image distortions, SimCLR helps in building a robust model capable of accurate image quality assessment. **Enhanced Learning from Distortions:** The framework's focus on maximizing similarity for similarly distorted images and maximizing dissimilarity for differently distorted images (even when content is similar) enables the model to learn a comprehensive distortion manifold. These capabilities make SimCLR an ideal choice for this project, addressing the challenges of assessing image quality in teledermatology where diverse and subtle image distortions can significantly impact diagnostic accuracy. The implementation details and insights gained from using SimCLR are foundational for the subsequent stages of model training and validation discussed in the following sections.

4.4.1 Framework Details

4.5 Regression Model Training and Validation

text

4.5.1 Model Selection and Training

4.5.2 Performance Metrics

4.6 Model Testing

The final model is tested against the labeled test set to evaluate its performance in real-world scenarios. Plots illustrating the model's performance across various quality criteria will be shown, highlighting areas where the model performs well or where there is significant variance, indicating uncertainty in quality assessment.

4.6.1 Testing with Labeled Test Set

Chapter 5

Results and Analysis

Realisierung

Dies ist das Hauptkapitel Ihrer Arbeit! Hier wird die Umsetzung der eigenen Ideen und Konzepte (Kapitel 3) anhand der gewählten Methoden (Kapitel 4) beschrieben, inkl. der dabei aufgetretenen Schwierigkeiten und Einschränkungen.

Evaluation und Validation

Auswertung und Interpretation der Ergebnisse. Nachweis, dass die Ziele erreicht wurden, oder warum welche nicht erreicht wurden.

Chapter 6

Discussion and Conclusion

text

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Appendix A

Supplementary Material

The following pages contain the supplementary material for this thesis. This section includes documents specific to project planning and management. The documents are attached in this order:

- Project Assignment
- Risk Management
- Project Planning

Documents and code relevant to the thesis can be downloaded from the following link:

[**https://github.com/Schoggi-Mimi/bachelor-thesis.**](https://github.com/Schoggi-Mimi/bachelor-thesis)

Aufgabenstellung

Modul:	Dept I BAA FS24
Titel:	Automated Image Quality Assessment in Teledermatology
Ausgangslage und Problemstellung:	ABIZ has been researching artificial intelligence applications in dermatology for the past decade with the objective to develop decision support systems to effectively support clinical practice. In collaboration with the University Hospital of Basel and the Swiss company Derma2go, we are tackling the issue of automatically assessing the quality of patient images for diagnosis, since this factor heavily impacts the effectiveness of teledermatology workflows.
Ziel der Arbeit und erwartete Resultate:	The objective of this work is to conduct an extensive review of state-of-the-art quality assessment methods in the general image domain and evaluate how they can be applied to teledermatology. The project deliverables include: <ul style="list-style-type: none"> - A comprehensive review of state-of-the-art image quality assessment methods. - A review of image quality criteria for teledermatology diagnosis. - An evaluation of selected quality assessment methods on public dermatology datasets. - A well-written repository enabling to reproduce reported results and assess the quality of new patient images.
Gewünschte Methoden, Vorgehen:	The project will start with a literature review of existing quality assessment methods and patient image quality criteria in dermatology. Together with the supervisor, adapted methods will be selected, which the student will then evaluate on public dermatology datasets. The student will present his work to the supervisor on bi-weekly meetings. One day before the meeting, the student will share a 1-page document describing in bullet points: <ul style="list-style-type: none"> - What work was performed during the last reporting period. - What work is planned for the next period. - Project status, comparison with planning, reasons for deviations if applicable. - Top three risks incl. planned measures. For the meeting, the student will prepare slides to present these information in more details.
Kreativität, Methoden, Innovation:	This thesis will encourage innovative approaches, including but not limited to proposing new metrics and relevant changes to adapt methods to the teledermatology context. The student will have the opportunity to fine-tune deep learning models on public dermatology datasets and work closely with both clinicians and researchers from ABIZ and the partner institutions.
Sonstige Bemerkungen:	Candidates should have a strong background in computer science. Prior experience with medical imaging or teledermatology is beneficial but not mandatory. The project will require a creative approach to problem-solving and an eagerness to work in interdisciplinary teams.

Projektteam

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Betreuer:in:	Dr. Ludovic Amruthalingam

Auftraggeber

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APPENDIX A. SUPPLEMENTARY MATERIAL

include
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project
planning
pdfs

Appendix B

Dataset

Detailed information on image quality assessment (IQA) databases:

- **LIVE** (Laboratory for Image & Video Engineering) dataset (Sheikh et al., 2006) includes 29 reference images and 779 manually distorted images corrupted by 5 types of distortions: JPEG compression (JPEG), JPEG2000 compression (JP2K), white noise (WN), Gaussian blur (GB), and simulated fast fading Rayleigh channel (FF). Each distortion type contains 5 or 4 distortion levels. Most images are 768×512 pixels in size. Each distorted image in this dataset is associated with a Differential Mean Opinion Score (DMOS), scaled from 0 to 100, where 0 indicates no perceivable distortion.
- **TID2008** (Tampere image database 2008) dataset (Ponomarenko et al., 2009) includes 25 reference images and 1700 distorted images corrupted by 17 types of distortions, with 4 levels for each distortion type. All images have a fixed resolution of 512×384 . This dataset provides MOS values and their standard deviations, with MOS ranging from 0 to 9, where 9 signifies a distortion-free image.
- **TID2013** (Tampere image database 2013) dataset (Ponomarenko et al., 2015) is extended from TID2008 (Ponomarenko et al., 2009) by increasing the number of distortion levels to 5, and the number of distortion types to 24. Therefore, 3000 distorted images are generated from 25 pristine images. The subjective testing and data processing steps are similar to that of TID2008. DMOS values for this dataset were derived from over half a million ratings given by nearly a thousand observers, with values ranging from 0 to 9, where higher values denote poorer image quality.
- **CSIQ** (Categorical subjective image quality (CSIQ) database) (D. M. Chandler, 2010) contains 30 pristine images and 866 distorted images corrupted by JPEG, JP2K, WN, GB, additive pink Gaussian noise, and global contrast decrements, with 5 or 4 levels for each distortion type. The resolution is 512×512 . Each image in CSIQ is associated with DMOS values obtained from subjective ratings by 25 testers, with DMOS values scaled from 0 to 1, where higher values indicate worse quality.
- **A57** (D. Chandler & Hemami, 2007) includes 3 pristine images and 54 distorted images corrupted by 6 types of distortions, with 3 levels for each distortion type. All images are in gray scale. The resolution is 512×512 .
- **WED** (Waterloo exploration database) (Ma et al., 2017) includes 4744 pristine natural images and 94880 distorted images corrupted by JPEG, JP2K, GB, and WN, with 5 levels

for each distortion type. The images have various resolutions. No human opinion score is provided, but the authors introduce several alternative test criteria to evaluate the IQA models.

Multiple Distortions IQA Databases

- **LIVEMD** (LIVE multiply distorted) (Jayaraman et al., 2012) database consists of 15 reference images and 405 multiply distorted images. The database includes one/double-fold artifacts. Each multiply distorted image is corrupted under two multiple distortion scenarios: Gaussian blur followed by JPEG and Gaussian blur followed by white noise. All images have a resolution of 1280×720 . DMOS values for each distorted image range from 0 to 100.
- **Multiply distorted image database 2013 (MDID2013)** (Gu et al., 2014): MDID2013 has a total of 12 pristine images and 324 distorted images. Each pristine image is corrupted successively by Gaussian blur, white noise, and JPEG. The images have resolutions of 768×512 or 1280×720 .
- **Multiply distorted image database 2016 (MDID2016)** (Sun et al., 2017): MDID2016 consists of 20 reference images and 1600 distorted images. Five distortion types are introduced, i.e., white noise, Gaussian blur, JPEG, JPEG2000, and contrast change (CC). The order of distortions is as follows: Gaussian blur or CC first, JPEG or JPEG2000 second, and white noise last. All distorted images are with random types and levels of distortions. The image resolution is 512×384 .

Screen Content IQA Databases

- **Screen Image Quality Assessment Database (SIQAD)** (Yang et al., 2014): SIQAD includes 20 pristine and 980 distorted screen content images (SCIs). Distortion types include white noise (WN), Gaussian blur (GB), color cast (CC), JPEG, JPEG2000 (JP2K), motion blur (MB), and layer segmentation-based compression, with 7 levels for each type. The images have various resolutions near 700×700 .
- **Screen Content Image Quality (SCIQ) Database** (Ni et al., 2017): SCIQ consists of 40 pristine and 1800 distorted SCIs corrupted by 9 types of distortions, including WN, GB, MB, CC, JPEG, JP2K, color saturation change (CSC), color quantization with dithering (CQD), and the screen content coding extension of High Efficiency Video Coding (HEVC-SCC). Five distortion levels are considered. The resolution is fixed at 1280×720 .
- **Cross-Content-Type (CCT) Database** (Min et al., 2017): CCT is constructed to conduct cross-content-type IQA research. CCT consists of 72 pristine and 1320 distorted natural scene images (NSIs), computer graphic images (CGIs), and SCIs. Two distortion types are considered, i.e., HEVC and HEVC-SCC coding, with 11 distortion levels for each type. The image resolution is either 1920×1080 or 1280×720 .
- **Hybrid Screen Content and Natural Scene Image Database (HSNID)** (Gu et al., 2020): HSNID has 10 pristine NSIs and 10 pristine SCIs, and 600 distorted NSIs and SCIs corrupted by WN, GB, MB, CC, JPEG, and JP2K, with 5 distortion levels for each type.

Authentic Distortions IQA Databases

- **LIVE in the wild image quality challenge database** (Ghadiyaram & Bovik, 2016) includes 1162 authentically distorted images captured using a variety of mobile devices. Complex real distortions, which are not well-modeled by the synthetic distortions are included. All images are cropped to the resolution of 500×500 . A novel crowdsourcing system was employed to gather over 350,000 opinion scores from 8100 observers, ensuring the objectivity of the MOS values obtained.

- **Camera image database (CID2013)** (Virtanen et al., 2015): CID2013 is designed to test no-reference IQA algorithms. It includes 480 real images captured from 8 typical scenes using 79 consumer cameras and mobile phones. The images are rated from 5 aspects: the overall quality, sharpness, graininess, lightness, and color saturation scales. The images are scaled to a size of 1600×1200 .

Appendix C

Degradation Types

As mentioned in Subsection 2.2.2, the dataset used in this thesis is augmented with synthetic degradations. The following figures Figure C.1, Figure C.2, Figure C.3, Figure C.4, Figure C.5, Figure C.6, Figure C.7 show the different levels of intensity for the degradations of each distortion group.

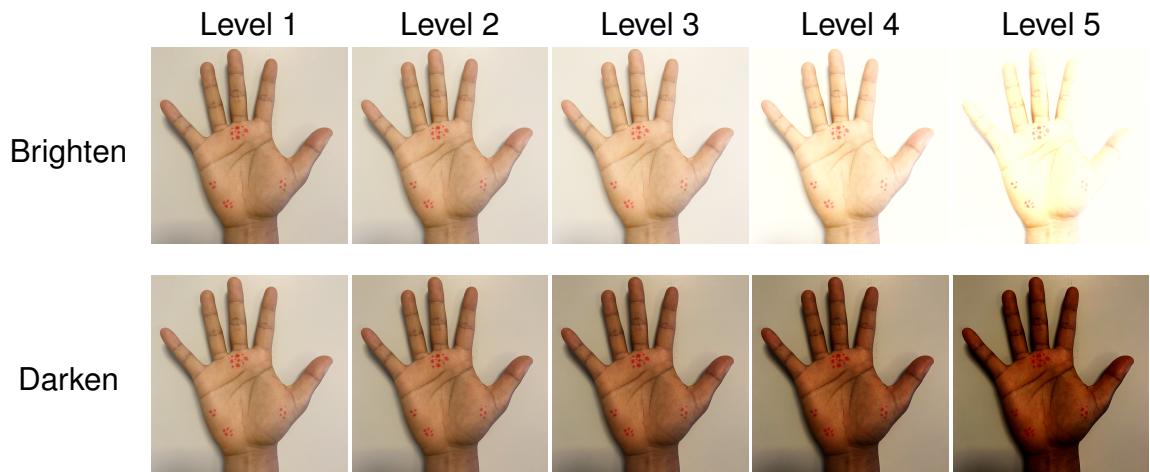


Figure C.1: Visualization of the degradation types belonging to the *Brightness change* group for increasing levels of intensity.

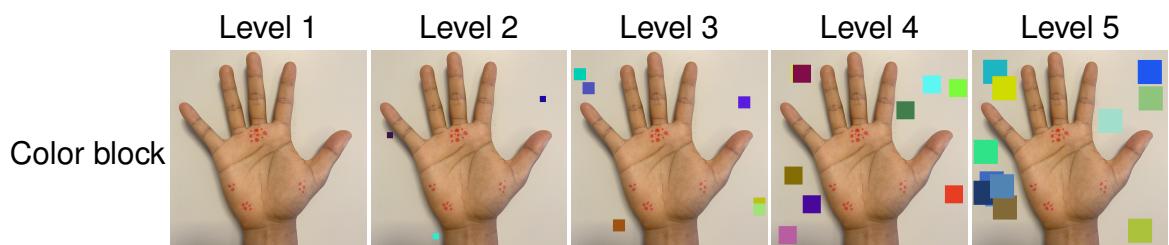


Figure C.2: Visualization of the degradation types belonging to the *Background color* group for increasing levels of intensity.

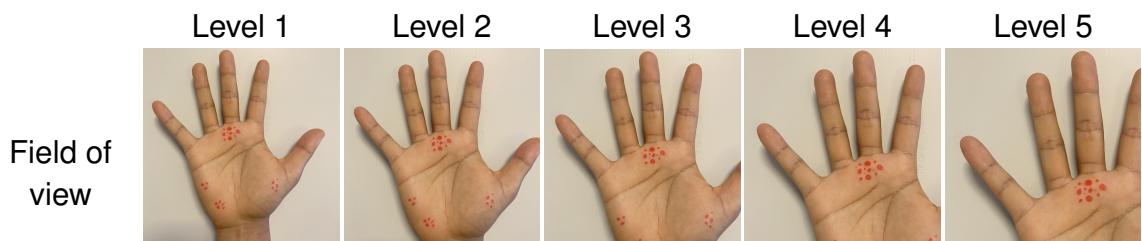


Figure C.3: Visualization of the degradation types belonging to the *Field of View* group for increasing levels of intensity.

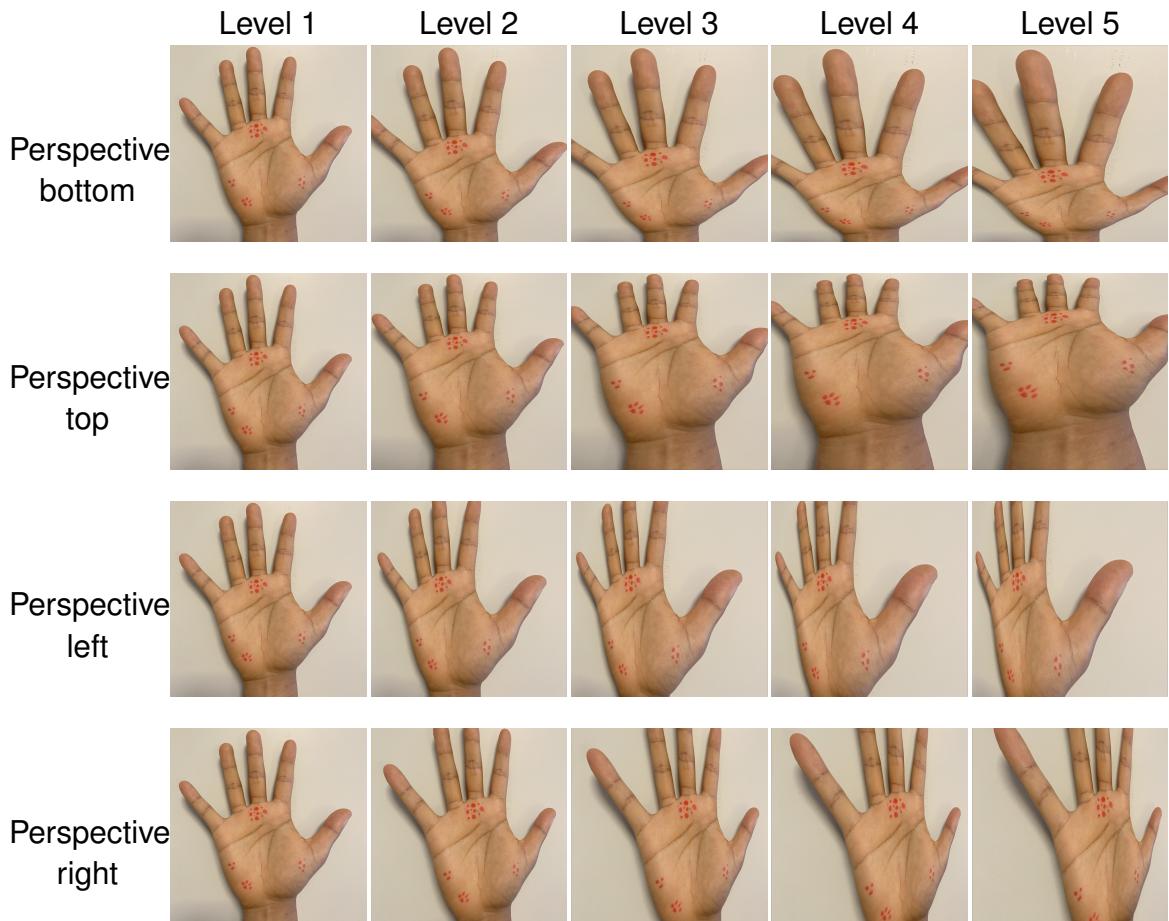


Figure C.4: Visualization of the degradation types belonging to the *Image orientation* group for increasing levels of intensity.

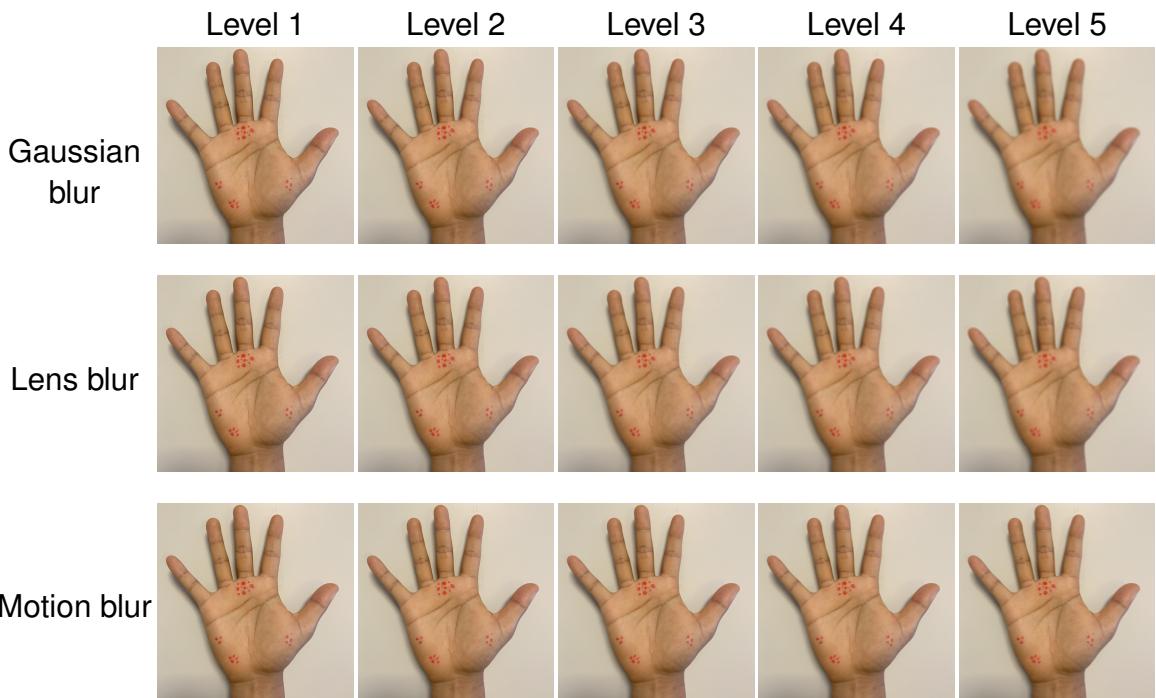


Figure C.5: Visualization of the degradation types belonging to the *Focus* group for increasing levels of intensity.

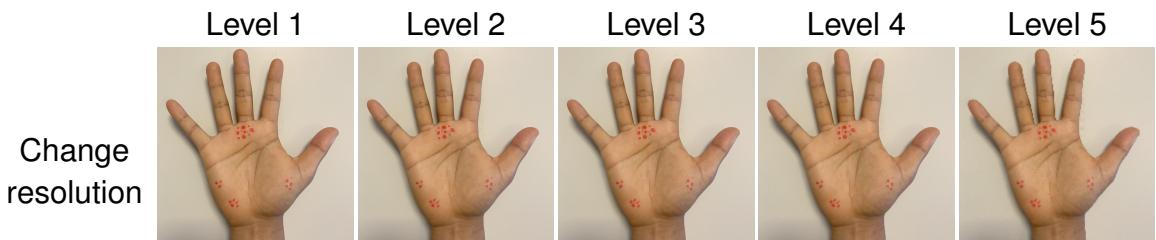


Figure C.6: Visualization of the degradation types belonging to the *Resolution* group for increasing levels of intensity.

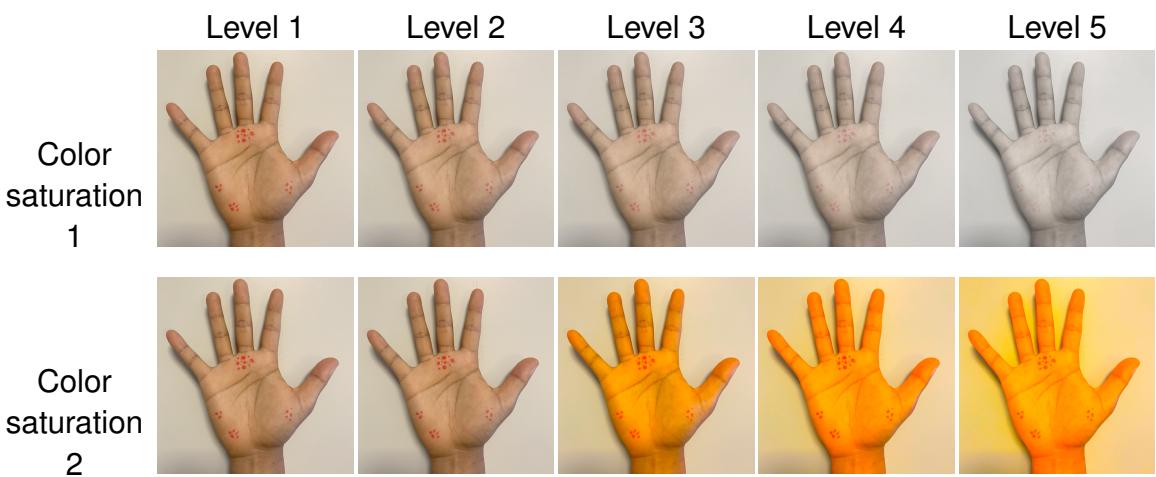


Figure C.7: Visualization of the degradation types belonging to the *Color calibration* group for increasing levels of intensity.

Appendix D

Code

Anhang, Abkürzungs-, Abbildungs-, Tabellen-, Formel-Verzeichnis, Literaturverzeichnis nicht vergessen!

Anhänge

Projektspezifisch können weitere Dokumentationsteile angefügt werden wie:

Aufgabenstellung, Projektmanagement-Plan/Bericht, Testplan/Testbericht, Bedienungsanleitungen, Details zu Umfragen, detaillierte Anforderungslisten, Referenzen auf projektspezifische Daten in externen Entwicklungs- und Datenverwaltungstools etc.

Listing D.1: Caption on PDF

```
import numpy as np
```