DEPARTMENT OF COMPUTER SCIENCE AND ENGINEERING
INDIAN INSTITUTE OF INFORMATION TECHNOLOGY, DESIGN AND MANUFACTURING KANCHEEPURAM
CHENNAI - 600127

Synopsis Of

No reference image quality assessment for visual perception and accomplishing tasks using machine learning techniques

A Thesis

To be submitted by

KIRUTHIKA S.

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Of

DOCTOR OF PHILOSOPHY

1 Abstract

In the early years of the twenty-first century, researchers have witnessed a proliferation of digital images for representing information. Advancement in multimedia technology is attempting to improve the quality of images in acquiring, processing, storing, and transmission. Evaluating the quality of an image is called as Image Quality Assessment (IQA). In the initial days, the quality of an image is assessed by humans. The score given by human experts is named as the human opinion score. Involving humans in the assessment is slow, complicated, expensive, subjective, and challenging to incorporate into automation models. Thus, resulting in contemporary way of quality assessment which aims to develop an automatic assessment model to quantify or assess the quality of image without involving human. An algorithmic way of evaluating the image is called as objective IQA. In the initial stages of objective IQA, evaluating the quality of an image has been done with the help of a reference image. Researchers have recently attempted to develop an another type of objective assessment metric called no reference IQA. No reference IQA assesses the quality of the image without using its reference image or the information extracted from the reference image.

This thesis presents No Reference IQA (NR-IQA) models for specific application specific, domain specific and a new paradigm of IQA named goal oriented IQA. Under domain specific NR-IQA, retinal image quality assessment and no reference IQA using non subsampled contourlet and curvelet transforms has been discussed to evaluate the quality of images, particularly for communication and entertainment industry. Goal oriented IQA (GO-IQA) which comes under the category of goal specific IQA has been discussed. The main objective of the model is to evaluate how good the image is in achieving a specific goal. The goal considered here is segmentation. The idea is to predict how well the image can be segmented by any arbitrary segmentation algorithm without executing any algorithm. Under application specific NR-IQA, two models have been discussed. They are to detect the presence of COVID 19 using chest CT scan images and to detect fake faces (computer generated faces) over real face images.

2 Objectives

Objectives of the thesis are as follows

- To develop an application specific no reference IQA
  - To detect the presence of COVID19 using chest CT scan image
  - To detect the fake faces (computer generated faces) over real face images
- To develop a domain specific no reference IQA
  - To classify the diabetic affected retinopathy fundus images (abnormal) over the normal images
  - To design a NR-IQA model for assessing the quality of the images used in entertainment industry
- To introduce a new paradigm of IQA, assessing the image for a specific goal, named as Goal-Oriented Image Quality Assessment (GO-IQA). GO-IQA means

assessing the quality in terms of whether the image will be suitable for achieving a specific goal or not. A goal can be depth computation, face recognition or face detection. The goal considered in this work is segmentation

3 Existing Gaps Which Were Bridged

In the literature, IQA has not been used to detect fake faces and COVID19. This thesis presents predictive models using IQA, for the first time to detect fake faces and COVID19. This thesis also proposed a new paradigm of IQA, called Goal-oriented IQA.

Domain specific IQA

- For assessing the quality of retinal images, both traditional machine learning (Shao *et al.*, 2017) and deep learning models (Raj *et al.*, 2020) have been proposed. Although these models perform well when the same dataset is used for training (80%) and testing (remaining 20%), when the model is validated on new dataset, they do not perform well (Raj *et al.*, 2019).

- Many No Reference IQA (NR-IQA) algorithms have been designed (Hassen *et al.*, 2013) (De and Masilamani, 2018) in the literature to assess the quality of images in the entertainment industry. Still, there is a scope to improve the accuracy of general purpose NR-IQA algorithms, particularly domain specific IQA can be explored.

Application specific IQA

- In medical domain, IQA has been used in evaluating the quality of medical images like CT scan (Cai *et al.*, 2017) and MRI images (Jang *et al.*, 2018). But IQA has not been used for detecting any diseases

- In digital forensics, IQA has been used to detect the spoofing attacks (Fourati *et al.*, 2020), fake biometric (Bakshi and Gupta, 2020) and forged iris (Galbally *et al.*, 2014). But IQA has not been used to detect fake faces generated by generative adversarial network

Need for Goal specific IQA

- Visual quality needs to be good for entertainment purposes, but for achieving a specific goal such as object detection, object recognition, depth map computation, etc. High visual quality does not necessarily guarantee more accurate object detection, depth map computation, etc.

- Although domain specific IQA algorithms are available, there is no goal oriented IQA algorithm available in the literature

- An interesting question to be answered is that given a goal (task) and an image, is the image good to achieve the goal by the best possible algorithm

- In an attempt to spur the research community to answer this question, we introduce a new paradigm of IQA, called goal oriented image quality assessment (GO-IQA)

4 Motivations and Contributions

Image plays a significant role in diagnosing the disease, particularly on the inner parts (invisible for the human eye) of the body. The pandemic has led to the doctor's consultation and diagnosis virtually. In this case, the need for quality assessment is mandatory in multiple stages. Like, in the laboratories, the quality of the image has to be assessed on the go from the images obtained from the imaging source. Similarly, the assessment has to be done in all clinical environments. It reduces the in-person visits to the clinical environment. This motivates us to design the retinal image quality assessment (RIQA). In general, from the literature, we learn that the RIQA is done for a particular disease, but not generic. The reason behind that is the components (parts of the retina) being considered for diagnosing each retinal disease are unique. For instance, in diabetic retinopathy, there will be an abnormal growth of new blood vessels, and for macular degeneration, the macula (part of the retina) will get damaged because of age-related factors. In the first case, the visual importance is given to the blood vessels, and in the second case, the priority is the macula. In our work, we assessed the quality of retinal images, particularly for diabetic retinopathy.

Detection of COVID-19 is a challenging task with the available clinical resources. The reason behind that is the test result of reverse transcription-polymerase chain reaction (RT-PCR) is not accurate and time consuming. Researchers found that the detection of COVID-19 at the early stage is possible and accurate in the chest images obtained using X-rays and CT scans. This motivated us to design an algorithm to detect the presence of COVID-19.

In the digital world, image plays a vital role in all areas. More importantly, the role of image in surveillance and security is very high. Recently, all the digital devices in specific, the smartphones and the applications in smartphones are giving access the images via recognizing the face of the human. In the same way, the growth of computer generated faces is becoming a main challenge to the researchers to detect them. As far as we know, the IQA features have not been used to detect computer generated faces. So, we designed an IQA based algorithm to detect the complex computer generated faces.

The entertainment industry needs good quality images for better visualization. In literature, more NR-IQA algorithms are developed to access the quality of natural images. However, still there is a scope to improve the accuracy of general purpose NR-IQA algorithms. In this direction, we developed an NR-IQA algorithm to assess the quality of natural images with better accuracy.

IQA has applications in all the domains, and its applications are also more comprehensive in each domain. Yet, IQA has not been developed for a specific goal. For example, the quality has been assessed for the visualization purpose but an interesting question arises here is that, whether the image is good for segmentation (goal) or not. Thus far there is no such algorithm to predict whether the given image is best suitable for segmentation (goal) or not (without executing a segmentation algorithm). In general, there is a need for a model to detect whether the given image is best suitable to achieve a particular goal or not. This intuition made us to develop a model to assess the images based on the purpose for which they are being used. We developed a goal-oriented image quality assessment (GO-IQA) to assess how good the image is to achieve the goal.

The goal we considered for the model is to perform segmentation.

5 Most Important Contributions

5.1 Retinal image quality assessment

Retinal image quality assessment is a NR-IQA model to classify the diabetic retinopathy affected retinal fundus images. The figure 1 shows the feature extraction for the model. Features extracted from the connected components play a vital role in discriminating

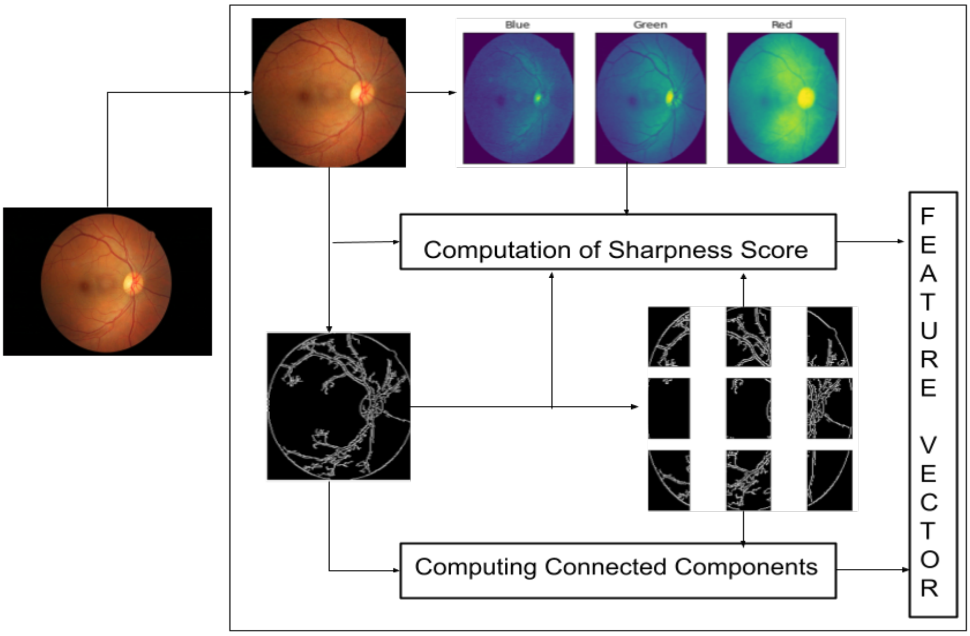

Figure 1: Feature extraction for retinal IQA

the images to check whether they are suitable for diagnosis or not. Reason behind that is that the visibility of nervous system has to be good for better diagnosing the diabetic retinopathy where as the number of connected components in the image will be high if the image has good nerve system. It will be less if the nerve system is not clear. XGBoost model is trained with the features extracted from the image along with its corresponding label. The proposed model outperforms the existing models on standard datasets.

5.2 NR-IQA using Non-subsampled contourlet and curvelet transform

No-reference IQA model using the curvelet and non subsampled contourlet transform is designed to quantify the quality of the images that are used in entertainment industry. Feature extraction has been done in two stages and they are shown in the figures 2 and

3. Once features are extracted, they are combined together to train the support vector regression model along with its human opinion scores. Performance of the model is evaluated with the database independence test and the images distorted with different distortions. The proposed model performs better than the existing models on the standard datasets.

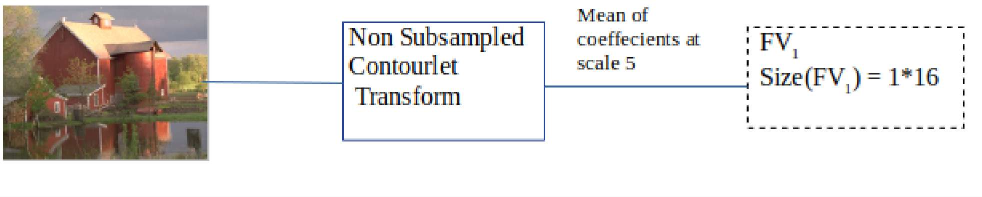

Figure 2: Step 1 in Feature Extraction

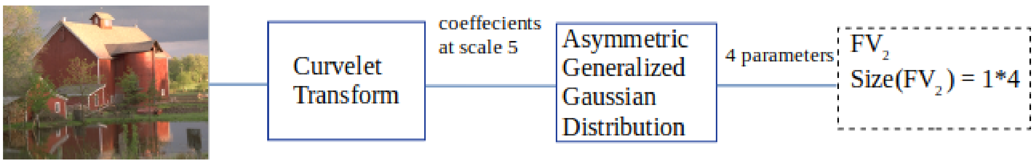

Figure 3: Step 2 in Feature Extraction

5.3 Goal oriented IQA

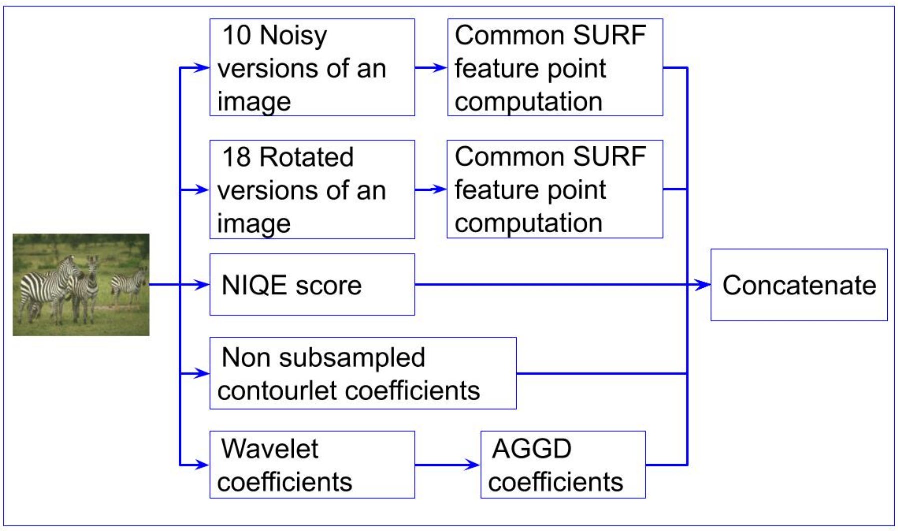

Figure 4: Feature extraction for GO-IQA.NIQE stands for Naturalness Image Quality Evaluator. AGGD - Asynchronous Generalized Gaussian Distribution, SURF - Speeded Up Robust Features

Goal Oriented IQA (GO-IQA) which is a new paradigm of IQA has been introduced in this thesis. GO-IQA is designed to evaluate the quality of an image but not in terms of visual perception. Evaluation will be based on how good the image is to achieve a specific goal rather than how good it is for visualization. Not all the images which are visually good will be suitable to achieve a goal. The segmentation is considered as the goal here. Figure 4 shows the feature extraction process. Figures 5 and 6, show the training and testing phase of the model. In general, all the NR-IQA models are trained with the features extracted from the image along with the human opinion score. But for GO-IQA features are trained along with the best F1 score as a label for an image. The reason behind that is that the end user is not humans, rather it is an image segmentation algorithm. Thus the model gives the best F1 score (GO-IQA predicted score) for an image without executing any segmentation algorithm. Scores predicted by GO-IQA model are well correlated with the state of the art segmentation model on the standard dataset.

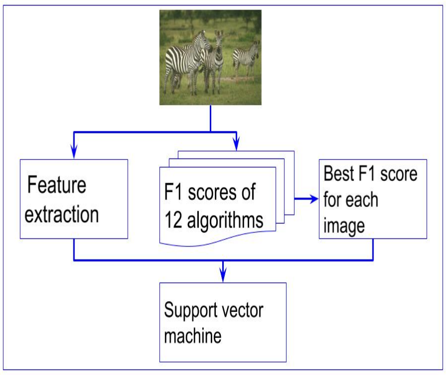

Figure 5: Training phase of GO-IQA

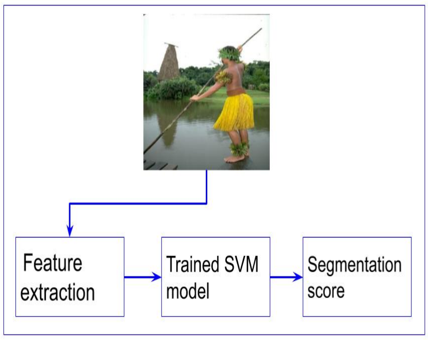

Figure 6: Testing phase of GO-IQA

5.4 Fusion of IQA and transfer learning for COVID19 detection using CT scan image

IQA based model is fused with transfer learning for COVID19 detection. The model classifies the COVID19 affected chest CT scan images over chest CT scan images affected by other pulmonary diseases. Overview of the COVID19 detection model is shown in the figure 8. Chest CT scan affected images are different from the normal CT scan images. As far as we know IQA has not been used to detect the disease. The observation here is that chest CT scan image that is affected by COVID19 is forming a pattern over the normal chest CT scan image. Also, the feature extracted based on the texture well discriminates the pattern when compared to other features. Label for the image is predicted by both the models and the final labelling is done by considering those labels along with their probability scores. Performance of the model is analyzed on the standard datasets and it outperforms when compared to the existing models.

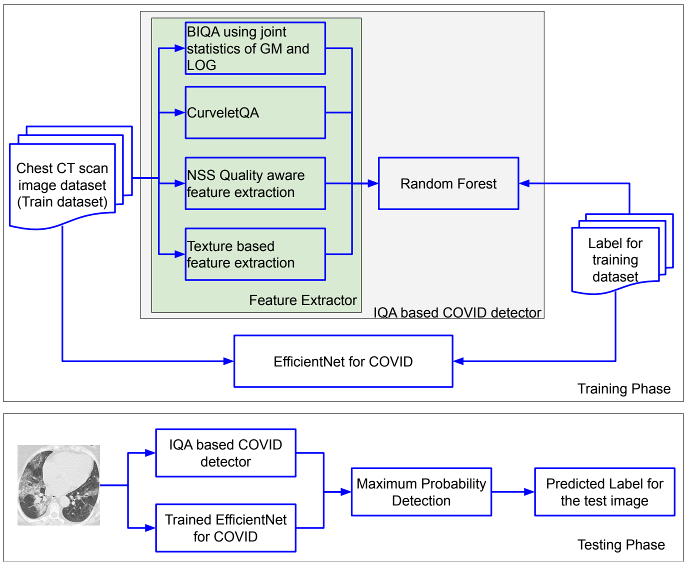

Figure 7: Overview of the COVID19 detection

5.5 IQA based fake face detection

IQA based fake face detection model is designed to classify the fake face images over the real face images. Fake faces considered here are generated by computer with the help of generative adversarial network. Among all the features, features extracted from Fast Fourier transform well discriminate the fake face over the real face images. Reason behind that is, that for visualization, both the fake and real faces look similar but in frequency domain they can be discriminated well. The proposed model outperforms the existing methods on the standard datasets.

6 Conclusions

This thesis mainly focuses on investigating the diverse ways of perceiving visual information and using it to address a wide range of problems. In brief, the work done can be concluded in following way

- A model is designed for assessing the retinal image quality and it has been validated with public and private datasets. The model outperforms the existing methods on public dataset. The future direction can be developing NR-IQA model to classify the diabetic retinopathy images over the images that are affected by other diseases.

- NR-IQA model using non subsampled contourlet and curvelet transform has been discussed to assess the quality of the images used in entertainment industry. Performance of the model is evaluated with the database independence test and the images distorted with different distortions. The proposed model performs well when compared to existing models. The future work can be developing a NR-IQA model in unsupervised way.

- A new paradigm of IQA called GO-IQA has been discussed. The goal considered for this work is segmentation. Proposed model is well correlated with the state of

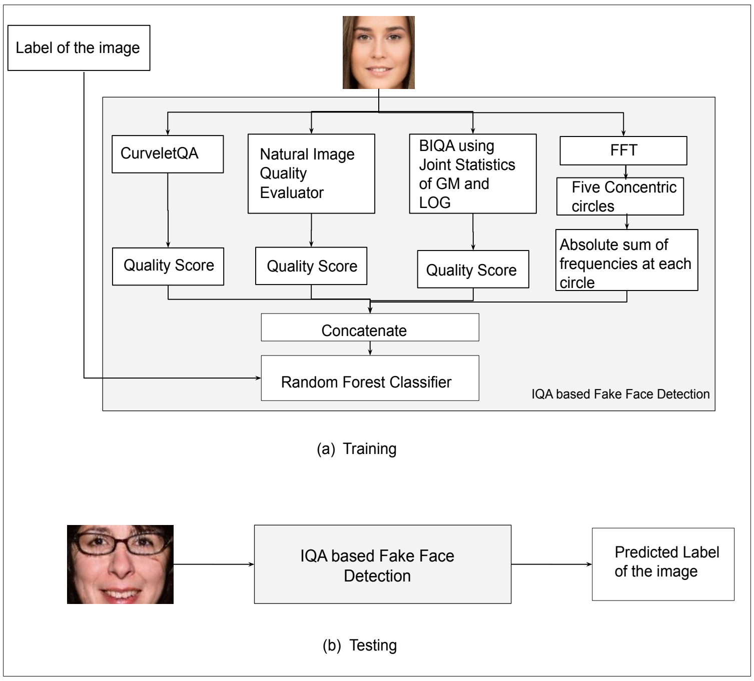

Figure 8: Overview of the IQA based fake face detection

the art segmentation model. In future, GO-IQA can be designed for the specific goal like depth computation, face recognition, object detection, etc.

- A model has been designed to detect the presence of COVID19 in CT scan images. IQA based COVID detection model is fused with transfer learning for COVID19 to bring the efficacy along with the explainability of the model. The model performs well when compared to the existing models on public dataset. In future, NR-IQA algorithms can be designed to detect different diseases using medical images like X-ray, CT scan, mammogram images etc.

- An IQA based fake face detection model is discussed. The fake faces considered here are the faces generated by computer with the help of generative adversarial networks. The model performs well when compared to existing methods on standard dataset. In future, NR-IQA can be designed to detect forged faces where face of person A is swapped with face of person B.

7 Organization of the Thesis

The work presented in the thesis can be classified into three categories: Application specific, domain specific and goal specific NR-IQA. Application specific NR-IQA refers to develop an NR-IQA method for a specific application. Domain specific NR-IQA refers to develop NR-IQA method for a particular domain. Goal specific NR-IQA refers to develop NR-IQA model for a specific goal, which is a new paradigm of IQA introduced in the thesis. The overview of the research work is shown in the figure 9.

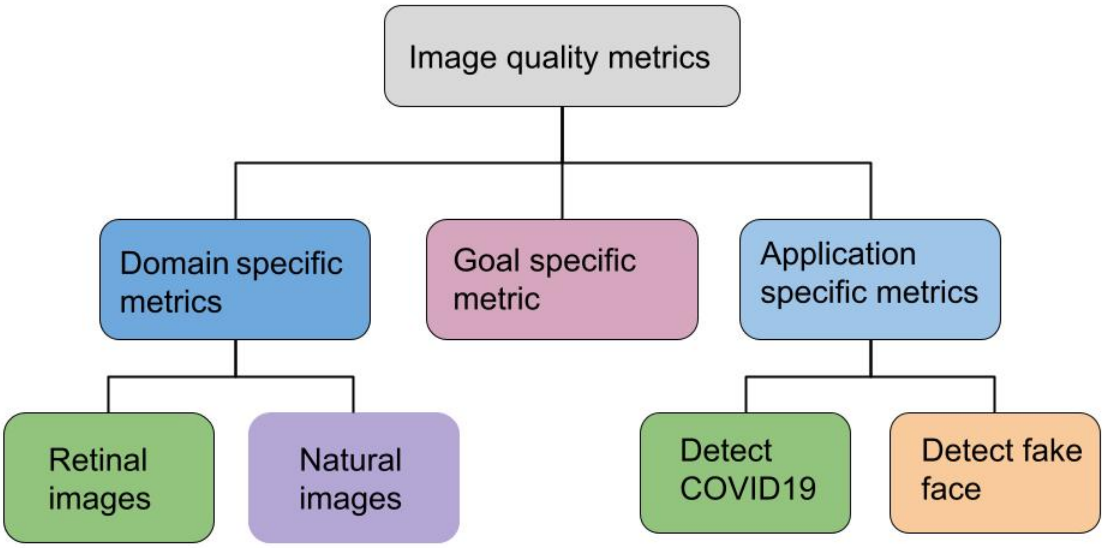

Figure 9: Overview of the research work

The proposed outline of the thesis is as follows

(a) Chapter 1: Introduction

(b) Chapter 2: Literature Survey

(c) Chapter 3: Retinal Image Quality Assessment using Sharpness and Connected Components

(d) Chapter 4: No Reference Image Quality Assessment using Non-Subsampled Contourlet and Curvelet Transform

(e) Chapter 5: Goal Oriented Image Quality Assessment

(f) Chapter 6: Fusion of Image Quality Assessment and Transfer Learning for COVID19 Detection Using CT Scan Image

(g) Chapter 7: Image Quality Assessment based Fake Face Detection

(h) Chapter 8: Conclusion

8 List of Publications

Journals

(a) Kiruthika S, Masilamani V, "Image quality assessment based fake face detection", Multimedia Tools Applications, Jan 2022, DOI: https://doi.org/10.1007/s11042-021-11493-9

(b) Kiruthika S, Masilamani V, "Goal oriented image quality assessment", *IET Image Processing*, April 2021, DOI: https://doi.org/10.1049/ipr2.12209

Conferences

(a) Kiruthika S, Masilamani V, and Pratik Joshi. 2021. "Fusion of image quality assessment and transfer learning for COVID19 detection using CT scan image". In Proceedings of the Twelfth Indian Conference on Computer Vision, Graphics and Image Processing (ICVGIP '21). Association for Computing Machinery, New York, NY, USA, Article 48, 1–9. DOI: https://doi.org/10.1145/3490035.3490307

(b) Kiruthika S, and Masilamani V, "Retinal image quality assessment using sharpness and connected components", Sixth IAPR International Conference on Computer Vision & Image Processing (CVIP2021), IIT Ropar

(c) Kiruthika S, and Masilamani V, "A Machine Learning Algorithm for No Reference Image Quality Assessment using Non-Subsampled Contourlet and Curvelet Transform", IEEE Conference on Information and Communication Technology, pp. 1-5, 2019

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3. **De, K.** and **V. Masilamani** (2018). No-reference image sharpness measure using discrete cosine transform statistics and multivariate adaptive regression splines for robotic applications. *Proc. Comp. Sci.*, **133**, 268–275.

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9. **Raj, A.**, **A. K. Tiwari**, and **M. G. Martini** (2019). Fundus image quality assessment: survey, challenges, and future scope. *IET Image Processing*, **13**(8), 1211–1224.

10. **Shao, F.**, **Y. Yang**, **Q. Jiang**, **G. Jiang**, and **Y.-S. Ho** (2017). Automated quality assessment of fundus images via analysis of illumination, naturalness and structure. *IEEE Access*, **6**, 806–817.