Declaration

I hereby declare that the work presented in this Thesis titled *"Quality Assessment and Enhancement of Retinal Fundus Images using Deep Learning Methods"* submitted to the Indian Institute of Technology Jodhpur in partial fulfilment of the requirements for the award of the degree of Doctor of Philosophy, is a bonafide record of the research work carried out under the supervision of *Dr. Anil Kumar Tiwari.* The contents of this Thesis in full or in parts, have not been submitted to, and will not be submitted by me to, any other Institute or University in India or abroad for the award of any degree or diploma.

Aditya Raj
P15VSS201

Certificate

This is to certify that the Thesis titled *"Quality Assessment and Enhancement of Retinal Fundus Images using Deep Learning Methods"*, submitted by *Aditya Raj (P15VSS201)* to the Indian Institute of Technology Jodhpur for the award of the degree of *Doctor of Philosophy*, is a bonafide record of the research work done by him under my supervision. To the best of my knowledge, the contents of this report, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

Dr. Anil Kumar Tiwari
Ph.D.Thesis Supervisor

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Aditya Raj
Ph.D. Student

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List of Symbols

Symbol	Description
I	An image
m	Horizontal dimension of image I
n	Vertical dimension of image I
$I(i,j)$	Pixel in I at location (i,j) with $i \in \{1,2,...m\}$ and $j \in \{1,2,...n\}$
$\mu(i,j)$	Local Mean in I for pixel $I(i,j)$
$\sigma(i,j)$	Local standard deviation in I for pixel $I(i,j)$
$\omega_{k,l}$	Circularly-symmetric 2D Gaussian weighting function
$\hat{X}_i$	Input feature vector for the i^{th} image
$\hat{W}_i$	Weight matrix for the i^{th} image
$\hat{Y}_i$	Predicted score vector for the i^{th} image
$\hat{E}_i$	Corresponding error matrix for the i^{th} image
L_{MSE}	Mean squared error loss function
L_{CCE}	Categorical cross entropy loss function
L_{MAE}	mean absolute error function
L_{SSIM}	SSIM Loss function
A	classification accuracy
P	Presicion
R	Recall
F_m	F-measure
R	Radius of a circle
DI	Darkness intensity
hI	Pixel value with highest frequency near border region of a fundus image
gI	Heuristically chosen intensity value

List of Abbreviations

Abbreviation	Full form
$2D$	Two-Dimensional
$3D$	Three-Dimensional
$ADAM$	Adaptive moment estimation
$AIIMS$	All India Institute of Medical Sciences
$ARIES$	Automatic retinal interest evaluation system
B	Blue Channel
CAD	Computer Aided Diagnosis
$CLAHE$	Contrast limited adaptive histogram equalization
CNN	Convolutional neural network
$CPBD$	Cumulative probability blur detection
CSF	Contrast sensitivity function
CT	Computed tomography
DD	Disk diameters
$DIBR$	Depth-image-based-rendering
DR	Diabetic Retinopathy
FC	Fully connected
$FIQuA$	Fundus image quality assessment
FOV	Field of view
FR	Full-Reference
G	Green Channel
GAN	Generative adversarial networks
GVD	Global vessel density
HVS	Human Visual System
IQA	Image Quality Assessment
ISC	Image structure clustering
ITU	International Telecommunication Union
JNB	Just noticeable blur
$k-NN$	K-nearest neighbor
$KROCC$	Kendall rank-order correlation coefficient
LFF	Local feature fusion
LRL	Local residual learning
LVD	Local vessel density
MAD	Most Apparent Distortion
MAE	Mean absolute error
MDM	Mathura Das Mathur
ML	Machine learning
MRI	Magnetic resonance imaging
MSE	Mean square error
NR	No-Reference
pdf	Probability density function
$PLCC$	Pearson Linear correlation coefficient
PLS	Partial least square
$PSNR$	Peak signal-to-noise ratio
R	Red Channel
RDB	Residual Dense Blocks
RDC	Residual-Densely Connected
$ReLU$	Rectified linear unit
$RMSE$	Root-mean-square error
RR	Reduced-Reference
SVD	Singular value decomposition
BUI	Uneven illumination over border region
MUI	Uneven-illumination over macular region
$SROCC$	Spearman rank-order correlation coefficient
$SSIM$	Structural Similarity Index
$SURF$	Speeded Up Robust Feature
SVM	Support Vector Machine
VAE	Variational autoencoders
VIF	Visual Information Fidelity