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ADVANCED IMAGE ANALYSIS OF CORNEAL ENDOTHELIAL DYSTROPHIES USING ARTIFICIAL INTELLIGENT CONVOLUTION FILTERS

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ABSTRACT

The human cornea is a complex structure composed of five distinct layers, each playing a crucial role in maintaining vision. Among these layers, the stroma stands out as the thickest, while the endothelium layer exhibits the highest cell density. The endothelium layer is characterized by hexagonally structured cells, which normally maintain the cornea's health and function. The major diseases such as Fuch's dystrophy (FD), advanced Fuch's dystrophy (AFD), posterior polymorphous corneal dystrophy, Irido corneal dystrophy (ICD), mild polymegathism, and corneal guttata (CG) plays crucial role in reduction of endothelium cells in cornea. To know the condition of endothelium cells we conducted a study using a specular microscope, capturing a total of 13 images from different patients, each exhibiting FD, AFD, ICD, CG etc., To analyze these images, we utilize the Artificial Intelligent Convolution Filter (AICF) algorithm, which enabled us to extract key parameters related to the endothelium layer. These parameters are instrumental in assessing the health of the corneal endothelium and understanding how different dystrophies affect cell morphology. The parameters extracted by the AICF algorithm include Mean Cell Area (MCA), This parameter quantifies the average cell size, with values ranging from 79.5 µm² to 3485 µm². Elongation of Endothelial Cells (EEC) measures the shape of endothelial cells and varies from 3.11 µm² to 3.98 µm². Compactness Factor (CF) reflects the closeness of endothelial cells, with values spanning from 0.62 µm² to 0.93 µm². Heywood Circularity Factor (HCF) assesses the roundness of endothelial cells and exhibits a range of 0.8 µm² to 1.98 µm². Coefficient of Variation (CV) provides insights into the variability in cell sizes, with values ranging from 10 µm² to 99 µm². Hexagonality of Endothelial Cells (HEC) indicates the regularity of cell shapes and varies from 46.6 µm² to 65.2 µm².The statistical parameters serve as valuable indicators of the overall health of the endothelial layer and offer significant insights into how different corneal dystrophies impact the morphology of these crucial cells. By studying these parameters, we can better understand the progression and effects of various corneal conditions on the corneal endothelium. The AICF algorithm efficiently extracts the clinical features with diagnostic quality results 1000 milliseconds, which enhances the clinical interpretation time by over 90%, The algorithm offers scalable and reliable solution for automated corneal image analysis.

Keywords: *Fuch's Dystrophy, Advanced Fuch's Dystrophy, Corneal Guttata, Artificial Intelligent Convolution Filter, Elongation Of Endothelial Cells, Compactness Factor.*

1. INTRODUCTION

Corneal most susceptible layers are epithelium, stroma, and endothelium which are more prone to diseases, the different protein concentric levels vary with respect to the condition of layer basement. any infection, injuries, genetic defects cause the major changes in protein concentric level in the corneal

layer [1,2]. Manual analysis of specular microscopic images poses critical challenges due to the variation in morphological cell, cell structure overlapping, and artifacts noise. Relay on traditional morphological techniques poses the challenge in real time support, and subtle morphological changes in early dystrophies often leads to unrecognized without sophisticated feature extraction and delayed treatment. Despite advancements in image segmentation and statistical modelling of the endothelium layer the lack of real time comprehensive profile is missing across patients, clinical overflow often rely on visual interpretation and inconsistencies. To address above problem the AICF system is implemented with great accuracy and quantify endothelial morphological metrics and classify dystrophic severity under 1 second wich supports the clinical workload and diagnosis time. This work follows a comparative experimental design, evaluating the proposed method on a dataset of 13 real-world dystrophic patient images. We compare the results with established morphological parameters in ophthalmic literature from diverse regions and methodologies, notably those presented in [5], [6], and [12]. The system's performance is also benchmarked against PSNR and MSE metrics to quantify noise suppression and image clarity

1.1 Fuch's Endothelial Corneal Dystrophy (FECD)

FECD cause severe vision problem and leads to blind impairment, a characteristic feature of the FECD was apparent cause of Endothelial cell loss. The central and peripheral part of the cornea is differently indexed according to the age group of a patient[3]. the refractive index of the cornea is different in each category aging at (0-19yrs),(20-39yrs),(40-59yrs),(60yrs),in each category the central and peripheral part of the cornea is morphologically analyzed[4].FECD causes progressive loss of endothelial cells extracellular cells are deposited in the form of guttae, swelling of the cornea due to critical cell density causes poor vision. The clinical course of FECD usually spans 10-20 years [5] [6]. The loss of endothelium cells leads to the opacity, pituitary adenylate cyclasea activating polypeptide (PACAP), Peptide leads to healthy and grand functionality of endothelial cells [7]. The corneal edema due to Fuch's dystrophy causes visual impairment. The confocal microscope, specular microscope, optical coherent tomography (OCT) are the best microscopes gives the ultra-clarity resolution about the dystrophy's that are encountered in each layer of the cornea [8] [9]. The regenerative cornea is a novel methodology where researchers are more indulge. Endothelium layer is important in keeping cornea transparency with aqueous humor fluid, in case of severity >85% need to transplant cornea in culturing endothelium cells. In addition to rhokinase (Rock) incubator cell therapy vehicle works directly on endothelium cells cultures it properly in order to regenerate it successfully [10]. Furthermore, the rhokinase (Rock) incubator cell therapy vehicle works directly on endothelial cells and cultivates them properly to successfully regenerate endothelial cells , The FED pressurizes the glaucoma-related nerve in the human eye, highlighted that the Fuch's endothelial cells regenerate with cell-related genes like S0X2, OCT4, LGR5, TP63 (P63), PS1P (P75NTR), PAX2, SOX9, AP2B1 (AP2b) [11]

1.2 Corneal Edema vs Advanced Fuch's Corneal Dystrophy

The cornea is a transparent part of the eye. Anything that interacts at the junction of stroma in cornea leads to blood vessel migration and pigmentation. Corneal edema will be categorized with respective grades, the grades are dependent upon the severity and condition of edema, (grade g0,g1,g2,g3,g4,g5,g6)[12]13].The corneal structure is important in the vision, peripheral, central, superior part of the cornea is monitored, the thickness of cornea depends on the periphery, central, superior part of the cornea[14].corneal dystrophies affect 0.09% of the population and are identified IC3D based as their genotype, phenotype diagnosis[15].The spherical structure and corneal central thickness(CCT), and mean simulated keratometry, corneal endothelial cells dysfunction leads to visual impairment. The endothelial cells have low improvement when compared with epithelial cells and mean refractive spherical equivalent can be measured by ophthalmologists to describe complete and healthy cornea [16].If acanthamoeba crystals present in the cornea which bends reflected light slight a bit and Changing of the degree of light slightly due to abnormal cells in the cornea[17].corneal endothelium quality improvises corneal graft survival, Corneal dystrophies untreated

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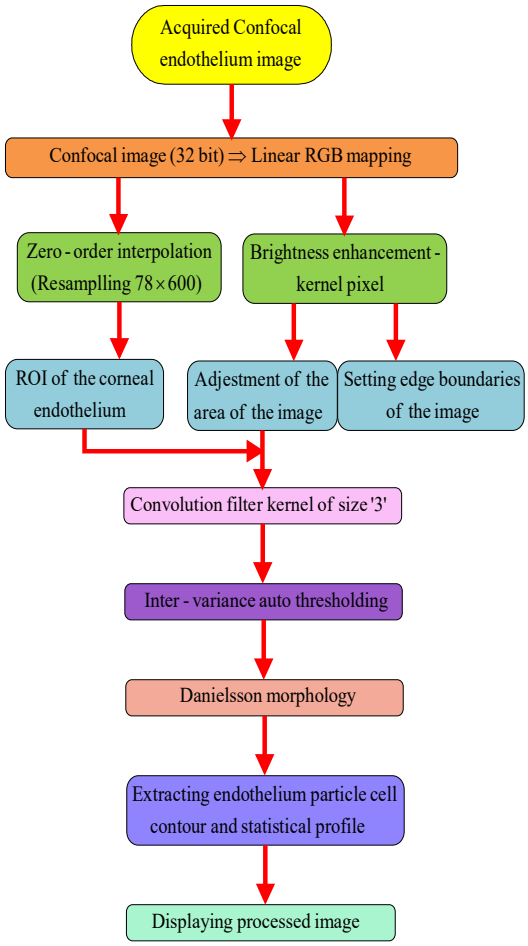

Fig 1 Proposed Methodology

leads to blindness and also results in corneal decompositions, as of now there are 40% of all corneal transplants happening all around the world[18]. Glutaminolysis generates a large amount in order to maintain the corneal endothelium cells properly. A lot of drugs have cationic amphiphilic structures and hydrophobic ring as well hydrophilic cationic amine allows to cross the cell membrane. These drugs lead to accumulation oftentimes in the cornea, the refractory corneal defects were induced in neurotrophic epitheliopathy [19][20]]. Regenerative medicine is applied to the corneal layers to get rid of the dystrophy's that caused to corneal layers, and also infants are most susceptible to FD, PPCD, etc. The PPCD are sometimes genetically encountered at birth stage also leads to endothelial keratoplasty [21].

1.3 ICE Syndrome:

ICE Syndrome in the cornea can be clearly monitored in confocal microscopy than that of scanning electron microscopy. Corneal edema also monitored specifically with confocal microscopy whereas it has failed in specular microscopy. Keratoconus is a noninflammatory disease, causing gradual paining and blurring the vision in the eye. Cornea gets bulged and causes refractive image changes in a cornea lens, which supported light imaging changes on the retina. Further, it can cause hazy and foggy vision. Evaluation and comparison of corneal hysteresis and corneal resistance factor in normal eyes and keratoconus infected eyes monitored clearly. the corneal nerve will be destroyed and leads to diabetic peripheral neuropathology if the severity of dystrophies is more. corneal conjunctiva, the mean corneal conjunctiva sensitivity did not differ significantly between rosacea patients. In normal and diseased types of corneas nitrotyrosine, nitric oxide, and nitric oxide synthesize isomers are an important chemical process happening in the cornea.

2. METHODOLOGY

2.1. Proposed methodology

A process of analyzing and enhancing confocal endothelium images for research or clinical purposes. Let's establish a meaningful link between these terms and their role in the image processing and analysis workflow: Considering Fig 1,
Acquired Confocal Endothelium Image: This is the original image of the corneal endothelium obtained using a confocal microscopy technique. Confocal Image 32-bit: Indicates the bit depth of the image, which can affect the dynamic range and precision of pixel values in the image.
Linear RGM Mapping: This term likely refers to applying a linear mapping technique to enhance the contrast or adjust the color balance of the image.
Zero-Order Interpolation (Resampling 78x600): This step involves resizing or resampling the image to a specific resolution (78x600 pixels) using zero-order interpolation, which replicates pixel values without interpolation. This can be used to standardize image dimensions. Brightness Enhancement: Kernel Pixel: Brightness enhancement suggests adjusting the overall brightness of the image using a kernel or filter that operates on individual pixel values.
ROI (Region of Interest): of the Cornea Endothelium: This term specifies selecting a specific area within the image that contains the corneal endothelium for focused analysis

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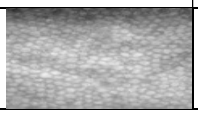
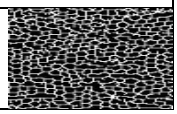
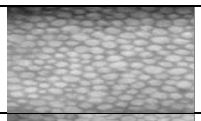
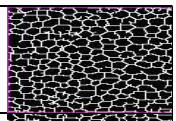
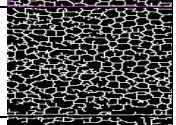
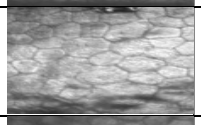
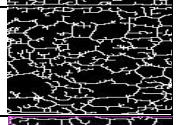
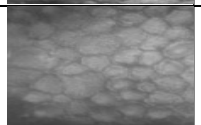
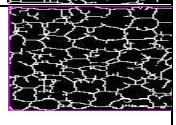
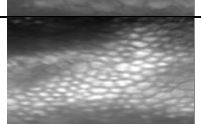
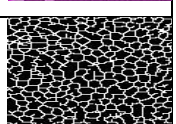
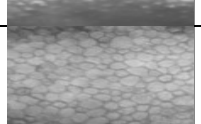
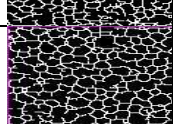
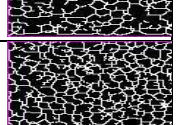
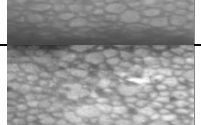
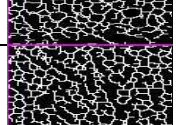
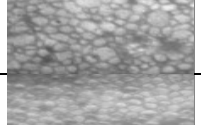
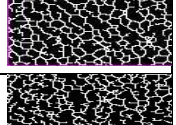
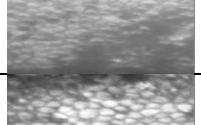
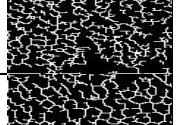
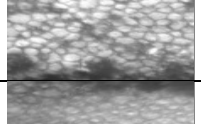
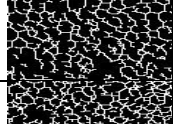
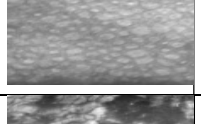
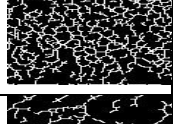
Adjustment of the Area of the Image: This likely involves cropping or resizing the image to isolate the region containing the corneal endothelium.
Setting Edge Boundaries of the Image: This indicates the delineation of the image edges, which can be important for further analysis and visualization.
Convolution Filter Kernel of Size 3: Suggests applying a convolution filter with a 3x3 kernel to perform operations like smoothing or sharpening on the image.
Inter Variance Auto Thresholding: This could involve automatically selecting a threshold to segment or separate features of interest in the image.
Danielsson Morphology: This is likely a reference to a specific morphological operation used for image processing, which may involve operations like dilation, erosion, or contour extraction.
Extracting Endothelium Particle Cell Contour and Statistical Profile: Refers to the process of isolating and outlining the endothelial cells' contours within the region of interest and collecting statistical data on these contours, which could include measurements like area, perimeter, or shape descriptors.
A comprehensive workflow for processing, enhancing, segmenting, and analyzing confocal endothelium images. This workflow is likely applied in research or clinical contexts to study the corneal endothelium, assess its health, and extract quantitative information about its morphology and structure. The five layers of cornea will encounter different dystrophies at their cell level. Map dot finger print dystrophy may attack to the first layer i.e. epithelial layer, direct traumatic dystrophy encounter to the second layer i.e. bowman's layer, granular dystrophy may encounter to the stroma layer which effects vision of the eye severely. The wilson's disease may affect the 4th layer i.e. Descemet's layer and causing severe vision loss in the human eye. Advanced fuch's dystrophy, Irido corneal dystrophy may encounter to the last layer of the cornea i.e. endothelium layer which leads to the permanent loss of vision in human eye

Table 2.1 Different Patients Cell Densities And Segmented Images

S. No	**Type of cornea/ Patient**	**Specular microscopic Image**	**Segmented endothelium Image**
I 1	High ECD		
I 2	Average Density 01/FD		
I 3	Average Density 02/FD		
I 4	Low Density 01/AFD		
I 5	Low density 02/ICD		
I 6	Surface folding/FD		
I 7	Mild Polymegathism/FD		
I 8	ICD		
I 9	Fuch's dystrophy		
I 10	Snail Tracks/PPCD		
I 11	Corneal Guttata 1		
I 12	Early stage of Corneal guttata		
I 13	PPCD		

As shown in Table 2.1, High ECD (Endothelial Cell Density) I1 refers to the number of endothelial cells per square millimeter. A "high ECD" suggests a healthy corneal endothelium with a high cell density. High ECD is indicative of a healthy cornea, and deviations from this norm may be associated with corneal diseases. Average Density 01/FD (Fuch's Dystrophy) I2,This term suggests a measure

of cell density in the context of Fuch's Dystrophy, a condition characterized by the gradual loss of endothelial cells. A decrease in cell density is a hallmark of Fuch's Dystrophy, and the "average density" may represent a diagnostic parameter. Average Density 02/FD I3, Similar to the previous term, this indicates a measure of cell density specifically associated with Fuch's Dystrophy. Multiple measurements of cell density in Fuch's Dystrophy may provide insights into disease progression or treatment response. Low Density 01/AFD (Advanced Fuch's Dystrophy) I4, Suggests a low endothelial cell density in advanced stages of Fuch's Dystrophy. As Fuch's Dystrophy advances, the cornea loses more endothelial cells, leading to a decrease in cell density. Low Density 02/ICD (Irido Corneal Dystrophy) I5, Indicates low endothelial cell density in the context of Irido Corneal Dystrophy. Low cell density may be a characteristic feature of Irido Corneal Dystrophy, affecting corneal health. Surface Folding/FD (Fuch's Dystrophy) I6, Surface folding is a morphological change in the corneal endothelium associated with Fuch's Dystrophy. Surface folding is a pathological feature observed in Fuch's Dystrophy, impacting corneal function. Mild Polymegathism/FD I7, Polymegathism refers to variability in cell size. "Mild polymegathism" suggests a relatively modest degree of cell size variation in Fuch's Dystrophy. Polymegathism is one aspect of endothelial cell morphology that can be affected in Fuch's Dystrophy. ICD (Irido Corneal Dystrophy) I8, Refers to Irido Corneal Dystrophy, a condition affecting the iris and cornea. ICD can lead to changes in corneal endothelial cell density and morphology. Snail Tracks/PPCD (Posterior Polymorphous Corneal Dystrophy) I9, "Snail tracks" are a distinctive pattern seen in the context of Posterior Polymorphous Corneal Dystrophy. These tracks are a characteristic feature of PPCD, providing a diagnostic clue. Corneal Guttata 1 I10, Corneal guttata are small, irregularly shaped excrescences on the corneal endothelium. Corneal guttata can be a sign of various corneal conditions, including Fuch's Dystrophy and PPCD. Early Stage of Corneal Guttata I11, Indicates the initial phase of corneal guttata development. Recognizing the early stages of corneal guttata is important for early diagnosis and intervention. PPCD (Posterior Polymorphous Corneal Dystrophy) I12, Refers to Posterior Polymorphous Corneal Dystrophy, a rare genetic disorder affecting the corneal endothelium. PPCD is characterized by changes in endothelial cell morphology and can lead to visual impairment. These terms encompass a range of corneal conditions and associated statistical information, highlighting the importance of assessing cell density, morphology, and pathological features in diagnosing and managing these disorders. Early detection and monitoring are crucial for effective treatment and preservation of vision in individuals with these conditions.

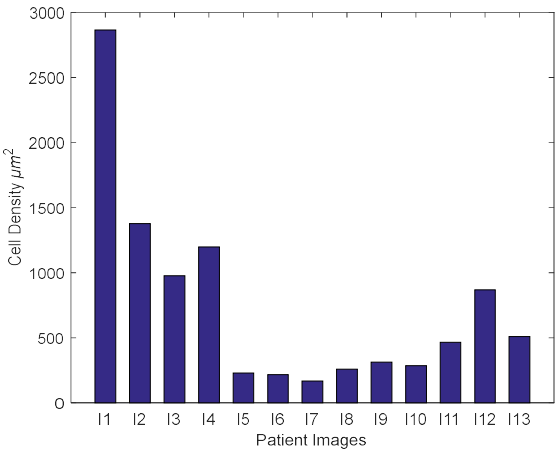


Figure 2.1 Cell Densities Of 13 Different Patient's Images

The specular microscopic images of different patients acquired and processed into the AICF algorithm, Considering Figure 2.1, The I1, I2, I3 images are high endothelial cell density or Normal cell density, Avg density01, Avg density 02 are FD images and their segmented images and densities of I1 (2865±10%, SD), I2 (1377±10%, SD), I3 (977±10%, SD), I4, I5, I6 images are low density 01, low density 02, surface folding followed by AFD and FD images and segmented images. The I4 image is AFD which indicates merging of adjacent cells which shows clearly in talble.2. figures. And the densities of I4 (1198±10%, SD), I5 (230±10%, SD), I6 (217±10%, SD) is shown in table.2, Similarly I7, I8, I9, I10 images are mild polymegathism or early stage of FD, and Irido-corneal dystrophy, FD, snail tracks posterior polymorphous corneal dystrophy followed by densities of I7 (168±10%, SD), I8 (259±10%, SD), I9 (312±10%, SD), and I10 (286±10%, SD and image I10 shows clearly tracks of snail in endothelium cells. I11, I12, I13 images are of corneal guttata, early stage of corneal guttata, and densities of I11 (466±10%, SD), I12 (868±10%, SD), I13(509±10%, SD) are shown in figure 2.2. The I13 image is posterior polymorphous corneal dystrophy which shows all endothelium cells are heavily damaged and no shape of hexagonality could be found in the image. Figure 2.2 shows '13' different patients images vs cell density, high

endothelium cell density usually observed in normal images, the cell density is 2865±10% SD, which is in normal range, ≤ 2400 cells/mm2 considered to be abnormal images, any dystrophy may cause change in cell density. >2400 cells/mm2 are normal images. The images '1' is normal range remaining '12' images are dystrophic images (I2-I13) images cell density is <2400 cells/mm2 which are abnormal in nature.

Table 2.2 Variation Of Mean, SD A Nd Areas Of 13 Different Patient's Images

Patients Images	Mean value	Standard Deviation	Area mm²
I1	0.64	2.2	0.2611
I2	0.9	3.04	0.2611
I3	0.88	3.33	0.2611
I4	0.35	2.15	0.2611
I5	0.47	2.45	0.2611
I6	0.54	2.36	0.2611
I7	0.62	2.17	0.2611
I8	0.52	2.65	0.2611
I9	0.48	2.48	0.2611
I10	0.60	2.68	0.2611
I11	0.43	2.62	0.2611
I12	0.55	2.59	0.2611
I13	0.61	2.56	0.2611

Considering table 2.2 all the images are interpolated with quadratic interpolation, The area doesn't change or unaffected during the process. All '13' images mean value is range in between 0.30 µm2 to 0.64 µm2, the standard deviation 2.5 µm2 to 3.3 µm2, the area of all images is 2.655*105 which remains unchanged due to interpolation of the images.

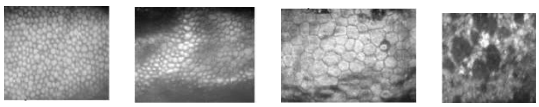
The auto metric threshold, All '13' images are processed, The lower threshold limit is '10' and upper threshold limit is '245', The minimum is '10' the upper is '245'. All the images are processed and lies in the range of 10 to 245 all the images has different thresholding values, The image I1 is 120, image I2 is 125, Image I3 is 130. All images lies in the range of 10 to 245. The dystrophic images like fuch's dystrophic image, advanced dystrophic image, posterior polymorphous corneal dystrophy, Irido corneal dystrophy, corneal guttate diseases encounter the endothelium layer causing which cell densities may change, Significantly the cell density is reduced. The mean values are also get nominal values. For normal images the mean, SD, lies in the nominal value. Lower limit 10 and upper limit 245

Mean Value: The mean value represents the average of some measured parameter across the patient images. In this dataset, the mean value ranges from 0.35 to 0.90. This parameter's context is not explicitly provided, so it's essential to know what it represents for a more precise interpretation.

Standard Deviation: Standard deviation measures the degree of variability or dispersion in the data. In this dataset, the standard deviation ranges from 2.15 to 3.33. A higher standard deviation indicates greater variability among the patient images.

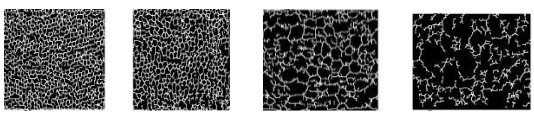
Area (mm²): The area likely represents the size or area measurement of some anatomical or pathological feature within the images. In this case, all patient images have the same area measurement of 0.2611 mm².While this table provides some statistical data, the context and interpretation may require additional information. Understanding what the mean value and standard deviation represent in this specific context is crucial for drawing meaningful conclusions. Additionally, knowing the significance of the common area measurement (0.2611 mm²) across all images would provide a clearer understanding of the dataset and its implications.

The fuch's dystrophy, advanced fuch's dystrophy, Irido corneal dystrophy, corneal guttate causes severe damage to the endothelial layer as shown in figure 2.2 a to d. All the images are acquired from specular microscope before processing into the algorithm the images are segmented with different manual and automated segmented techniques like metric thresholding, etc. the segmented images provides boundary of endothelial cells very clear and easy to identify counters as shown in figure 2.3.



(a) (b) (c) (d)

Figure 2.2: (a) Fuch's dystrophy (b) Advanced fuch's dystrophy c) Irido corneal dystrophy d) corneal guttate



(a) (b) (c) (d)

Figure 2.3. Segmented Images of: (a) Fuch's dystrophy (b) Advanced fuch's dystrophy c) Irido corneal dystrophy d) corneal guttate

In this work, the developed methodology applied to the fifth layer i.e. endothelium layer. In future the same algorithm or little bit change in methodology

has applied to the remaining layers and their corresponding dystrophies. The same algorithm can be applied to identify map dot-finger print dystrophy. Epithelial basement membrane dystrophy similarly direct traumatic contact in bowman's layer can be identified. Same way granular dystrophy in stroma layer can also be identified with proposed algorithm. Similarly, fuch's dystrophy and Wilson dystrophy may identified with proposed algorithm. All the remaining four layers dystrophies are identified to protect the vision of human eye.

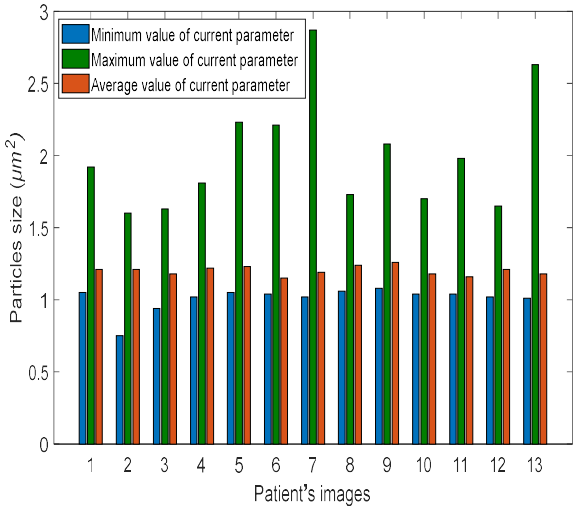


Figure 2.4. Particles sizes of 13 different patient's images

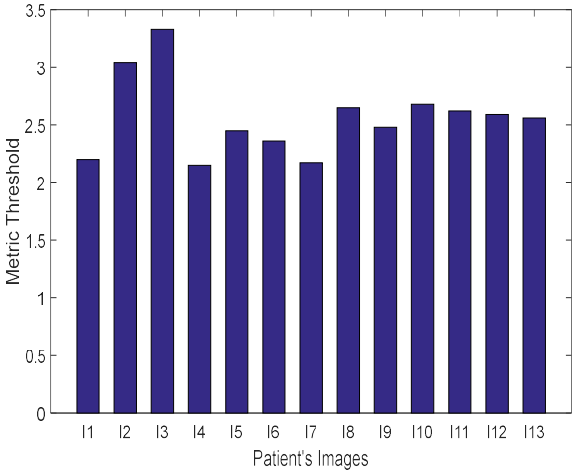


Figure 2.5 Metric Threshold of I1-I13

Figure 2.4, shows cell particle minimum range and maximum value which is standard measurements, the minimum value is 1 µm2 and maximum value is 2.4 µm2, below 1 µm2 and above 2.4 µm2, cell particle diameter is discarded. The Total '13' images are processed, the minimum value for I1 is 1.05 µm2 and maximum value is 1.92 µm2, the I2 0.75 µm2 and maximum value is 1.6 µm2. All images minimum range is > 1 µm2 and < 2 µm2, and maximum range is >1.5 µm2 and < 2.4 µm2. The mean value of the I1 is 1.31 µm2, I2 (1.21 µm2), I3(1.18 µm2), I4(1.22 µm2), I5(1.23 µm2),I6(1.15 µm2),I7(1.19 µm2),I8(1.24 µm2),I9(1.26 µm2),I10(1.18 µm2),I11(1.16 µm2),I12(1.21 µm2). I13(1.18 µm2). The mean value of I1 is 1.31 µm2 for normal images, I2 to I13 images has less mean value < 1.31 µm2 for abnormal images. I1 to I13 images mean values, Standard deviation and area of the images. I1 to I13, SD varies ranges from 2.00 µm2 to 3.00 µm2, and area remains unchanged as all the images are interpolated with quadratic interpolation. As shown in fig 2.5, the Metric Threshold values for 13 different patient images (I1 to I13). The highest bars appear for I3 and I4, indicating that these images have the largest Metric Threshold values (around 3.6 to 3.7). In contrast, I6 exhibits the lowest threshold (approximately 2.3), suggesting a notable drop in the measured parameter for that particular image. Most of the remaining images cluster between 2.5 and 3.0, reflecting moderate values of the Metric Threshold. This distribution highlights potential variability among patients' images, where certain cases (like I3 and I4) stand out with higher thresholds, possibly indicating distinct or more pronounced features in the corneal endothelium, whereas others (such as I6) may point to reduced or altered structural characteristics. The traditional methods rely on highly manual tracing, thresholding where as AICF algorithm integrates image enhancements and feature extraction with in single step, the particle filter in our pipeline discards outliers based on an empirically derived size range (1 µm² to 2.4 µm²), a step missing in earlier studies like Chandra & Murari (2020) [12,13]. Moreover, while past systems required up to 15 minutes per image [10], our system consistently delivers statistically rich results in under 1000 milliseconds, a 90% reduction in processing time. As compared to the techniques the AICF method incorporates dynamic auto thresholding range of 10 to 245 to adapt to pixel variability in diverse dystrophic presentations, enhancing segmentation reliability. Thus, the proposed method significantly aligns with clinical needs for speed, accuracy, and reproducibility.

3. CONCLUSION

The human cornea, with its five distinct layers, plays an indispensable role in maintaining our vision.

Among these layers, the endothelium stands out for its exceptionally high cell density and hexagonal cell structure, which are vital for corneal health and function. However, this delicate balance can be disrupted by a variety of corneal dystrophies, including Fuch's dystrophy (FD), advanced Fuch's dystrophy (AFD), posterior polymorphous corneal dystrophy, Irido corneal dystrophy (ICD), mild polymegathism, and corneal guttata (CG).To delve deeper into these alterations, our study employed a specular microscope to capture 13 images from diverse patients showcasing various corneal dystrophies. These images were meticulously analyzed using the Artificial Intelligent Convolution Filter (AICF) algorithm. This advanced algorithm allowed us to extract key parameters related to the endothelium layer, referred to as Layer 5.These parameters, including Mean Cell Area (MCA), Elongation of Endothelial Cells (EEC), Compactness Factor (CF), Heywood Circularity Factor (HCF), Coefficient of Variation (CV), and Hexagonality of Endothelial Cells (HEC), provided a comprehensive assessment of endothelial cell morphology and variability.The statistical analysis revealed a wide range of values within each parameter. Mean Cell Area (MCA) ranged from 79.5 μm^2 to 3485 μm^2, demonstrating significant variability in cell size. Elongation of Endothelial Cells (EEC) displayed values between 3.11 μm^2 and 3.98 μm^2, indicating varying cell shapes. Compactness Factor (CF) values spanned from 0.62 μm^2 to 0.93 μm^2, showcasing differences in the closeness of endothelial cells. Heywood Circularity Factor (HCF) exhibited a range of 0.8 μm^2 to 1.98 μm^2, highlighting diversity in cell roundness. Coefficient of Variation (CV) showed a wide variability, with values between 10 μm^2 to 99 μm^2, emphasizing the range of cell size fluctuations. Hexagonality of Endothelial Cells (HEC) varied from 46.6 μm^2 to 65.2 μm^2, indicating different degrees of regularity in cell shapes.These statistical parameters are invaluable tools that serve as indicators of the overall health of the endothelial layer. They offer profound insights into the precise ways in which various corneal dystrophies impact the morphology and structure of these essential cells. Through the meticulous study of these parameters, we are better equipped to comprehend the progression and effects of different corneal conditions on the corneal endothelium, ultimately paving the way for more effective diagnosis and treatment strategies in the field of corneal health.

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