Enhanced Fusion Approach to Diagnose ILD and Improve Patient Outcomes

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Abstract— **Interstitial lung disorders (ILDs) are a group of ailments marked by lung fibrosis (scarring). The four primary groups of ILDs are Nodule, Idiopathic Pulmonary Fibrosis (IPF), Sarcoidosis, and Honeycomb. Detecting these ILDs at an early stage can be facilitated by employing image enhancement methods based on wavelet transform and IHS transform-based techniques. Wavelet transforms, a mathematical method, can capture alterations in edges and textures at different scales in photographs. The IHS method, a commonly used sharpening technique, involves converting a color image from the RGB space to the IHS space through various transformations. By applying image enhancement techniques and evaluating them using parameters such as Peak Signal to Noise ratio (PSNR), Structural Similarity Index Method (SSIM), Mean Square Error (MSE) across different pulmonary image modalities, more accurate extraction of abnormalities can be achieved. The SVM classifier utilizes extracted features from enhanced images to classify the disease, leading to improved prognosis, prevention of severe conditions, and early diagnosis of ILDs.**

Keywords— *Idiopathic pulmonary fibrosis, Honeycomb, Wavelet Transform, IHS Transform, Mean Square Error (MSE), Structural similarity index method (SSIM), PSNR.*

I. INTRODUCTION

Persistent malignancies in the bronchial tissue can have significant effects, with manifestations falling into two main categories: parenchymal destruction leading to local lung density reduction known as emphysema, and inflammation and scar formation causing increased lung density referred to as interstitial changes [1] [2]. Interstitial lung diseases, sometimes known as ILDs, are a grouping of more than 200 different lung ailments, primarily impact the lung parenchyma, although they can also affect the vascular system and airways. Evidence suggests that certain ILDs, especially idiopathic pulmonary fibrosis (IPF), can be detected at an early stage through radiographic or chest computed tomography (CT) scans [3]. Interstitial lung abnormalities (ILA), visual indicators of these alterations, are associated with higher mortality, impaired lung function, and a genetic mutation linked to IPF. With the pervasive use of CT scanning, the high mortality rate associated with IPF, and the limited efficacy of current treatments, it is becoming increasingly important to accurately identify early interstitial changes before they progress to end-stage fibrosis [4] [5]. While visual analysis of CT scans remains the primary method for medical imaging interpretation, objective analytical techniques are gaining recognition for their ability to quantify abnormalities and classify disease subtypes in CT imaging [6].

Inflammatory Lung Disease: A variety of conditions that cause lung inflammation and scarring are referred to as "interstitial lung disease" (ILD). ILD symptoms include a dry cough and breathing difficulties. ILD can be caused by inhaling hazardous substances, taking medication, receiving radiation therapy, having connective tissue issues, and other factors. ILD typically causes permanent lung damage. ILD causes tissue damage between the blood vessels that surround the small air sacs (alveoli) in your lungs. Transferring oxygen from your lungs to your body will be more challenging as a result [7].

Inflammatory Lung Disease: Interstitial lung disease (ILD) comprises a spectrum of conditions marked by inflammation and fibrosis of the lungs. ILD is characterized by a dry cough and respiratory difficulties. Various factors can contribute to ILD, such as exposure to hazardous substances, certain medications, radiation therapy, connective tissue disorders, and other causes. ILD typically leads to permanent lung damage, specifically affecting the tissue between the blood vessels surrounding the small air sacs (alveoli) in the lungs. As a result, the transfer of oxygen from the lungs to the body becomes more challenging [8] [9]. When diagnosed with interstitial lung disease, the affected parts of the lungs, which play a crucial role in oxygenating the blood and tissues, suffer damage and scarring. This scarring hamper breathing and often leads to persistent coughing. The reduced oxygen levels can cause constant fatigue. As the damage progresses, it can give rise to life-threatening complications, including lung infections and respiratory failure, where the body experiences oxygen deficiency or an excessive buildup of carbon dioxide. There are over 200 different types of interstitial lung diseases, each with its own characteristics [5]. Two different lung disorders are shown in figure 1.
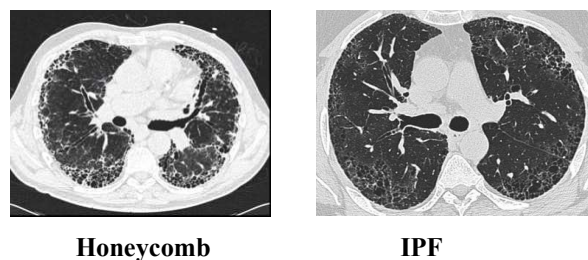

Honeycomb   **IPF**

Fig. 1. Variant Lung syndromes.

Smoking profile leads to higher risk of developing interstitial lung disease. Additionally, having certain diseases or disorders such as connective tissue disease, hepatitis C, tuberculosis, pneumonia, or chronic obstructive pulmonary disease (COPD) increases the likelihood of ILD. It is important to avoid exposure to substances like asbestos, silica, mold, fungus, or bacteria that can irritate the lungs [10]. Interstitial lung disorders can manifest in various forms, ranging from mild to severe. ILD typically leads to permanent

lung damage, and the most severe cases are progressive, meaning the disease worsens over time.

The significance and causes of ILD include experiencing shortness of breath that worsens with physical activity, a dry cough, fatigue, and chest discomfort. Symptoms usually start off mild but progress gradually over months or years. Depending on the underlying cause of ILD, additional symptoms may be present. Accurate medical diagnosis can be provided by a healthcare professional [11].

II. LITERATURE SURVEY

Hirani NA, Cottin V, Hotchkin DL, et al. explained about the rarity of interstitial lung disorders (ILDs) and how it causes progressive fibrosis. Progressive fibrosis decreases lung function, respiratory symptoms, immune modulator response, quality of life, and possibly early mortality. Slower-fibrosing ILDs such idiopathic pulmonary fibrosis [12] [1]. Idiopathic nonspecific interstitial pneumonia, unclassifiable idiopathic interstitial pneumonia, ILDs associated with connective tissue disorders (like rheumatoid arthritis), fibrotic chronic hyper sensitivity pneumonitis, fibrotic chronic sarcoidosis, and other occupational exposures may have a progressive-fibrosing phenotype [13] [14]. Differentiating ILDs requires rigorous clinical, radiological, and histological evaluation. Accurate and timely diagnosis is critical for optimal patient care. P Bianchi, S Danese, DJ Lederer, and GP Cosgrove. The past IPF and other interstitial lung disorders (ILD) have poor prognoses. We established an online questionnaire and conducted a nationwide survey of patients with a self-pronounced prognosis of ILD to gain insights into the diagnostic experience and identify potential barriers to a speedy and accurate analysis. methods: 600 pre-unique individuals completed the forty-item online survey. The recruitment and screening process ended when the objective number of replies was met. Adult U.S. citizens with IPF or another ILD can join [15].

Washko GR, et al. Justification and goals: This study examines two random methods for detecting early interstitial lung illness in chest CT images. Methods and components A sequential reader and a group consensus interpretation system were tested on CT images of the COPDGene project's first group of 100 people from a single university. CT scans are graded on the basis of the presence of parenchyma abnormalities caused by ILD: 0 is normal, 1 is uncertain, 2 is suspicious, and 3 is typical. Statistical analysis of early individuals with ILD as compared to regulates concluded. Hunninghake GM Interstitial lung abnormalities have been linked to a syndrome that includes imaging abnormalities, restrictive physiological and exercise impairments, an increased incidence of histopathological findings, and genetic predictors found in idiopathic patients [16] [17]. A recent longitudinal study found that interstitial anomalies qualitatively and quantitatively increase lung characteristic decline, interstitial lung disease medical diagnoses, and mortality by twofold. This viewpoint covers early pulmonary fibrosis detection, preceding data, and four key efforts. These efforts include identifying populations that may benefit from screening, developing standards for characterising and reporting imaging findings from patients with existing CTs, developing consensus statements on when undiagnosed and asymptotic imaging abnormalities should be considered diseases, and developing efficient secondary prevention trials.

Rosas IO, Hunninghake GM, and Doyle TJ Full-size high-resolution computed tomography in scientific and research settings has improved the diagnosis of chronic and untreated ILA. We found ILD in 1 in 12 smokers' high-resolution computed tomography images, but the long-term implications are unknown. Asymptomatic and untreated ILA sufferers have medically severe interstitial lung disease (ILD)-like lung capacity declines, operational blockages, rapid pulmonary symptoms, histopathologic changes, and molecular profiles [18]. Inflammatory lung disease, COPD smokers, and lungs with fibrosis groups were studied for these outcomes. These data suggest that ILA may indicate subclinical ILD or lung fibrosis among some at-risk individuals. Our limited understanding of ILD causes and plant histories, as well as the lack of effective treatments, has piqued interest in this topic. This perspective helps us distinguish previous and contemporary research on radiologic, physiological, and molecular approaches to detect preclinical ILD. We explore the limitations of pass-sectional studies and the need for longitudinal studies to determine the predictive and therapeutic effects of subclinical ILD in populations prone to clinically severe ILD [19].

Randi G, Guercio L, Verselet N, et al.: We assessed the prevalence of interstitial lung disease (ILD) in a group of smokers who were included in a lung cancer screening trial. In the Multicentric Italian Lung Detection (mild) trial, 692 heavy smokers were recruited, and two observers independently reviewed each of their computed tomography (CT) scans for the presence of anomalies associated with ILD. The four CT kinds that were taken into account were indeterminate, breathing bronchiolitis (RB), other chronic interstitial pneumonia (OCIP), and regular interstitial pneumonia (UIP). In the end, those subjects who received a second CT scan three years later were examined for ILD progression. In (0.3%) of 692 patients and 26 (3.8%) of 692 patients, respectively, the UIP sample and the OCIP sample were discovered. Out of 692 individuals, 109 (15.7%) showed CT abnormalities that were consistent with RB, and 21 (3%) had an ambiguous CT pattern [20]. Age, male sex, and current smoking history were all associated with the prevalence of OCIP and UIP (blended) patterns, even if the connection did not achieve statistical significance. Three (25%) of the 12 OCIP patients who received a repeat CT three years later had worsened conditions. In populations undergoing lung cancer screening, the occurrence of ILD on a thin-section CT, probably brought on by smoking, is frequent and shouldn't be disregarded.

III. PROPOSED APPROACH

In the proposed method, image processing and some of the machine learning techniques are used as SVM classifiers. Image enhancement techniques, wavelet transform and HSI methods are accustomed for enhancing medical images. The machine learning algorithm is been used to train the different images and features considered in the two classes of lung disorders as honeycomb, idiopathic pulmonary fibrosis, which are types of Interstitial lung disease.

Using the input images from test data and trained dataset the classification of images as the type of disease [21] [22].
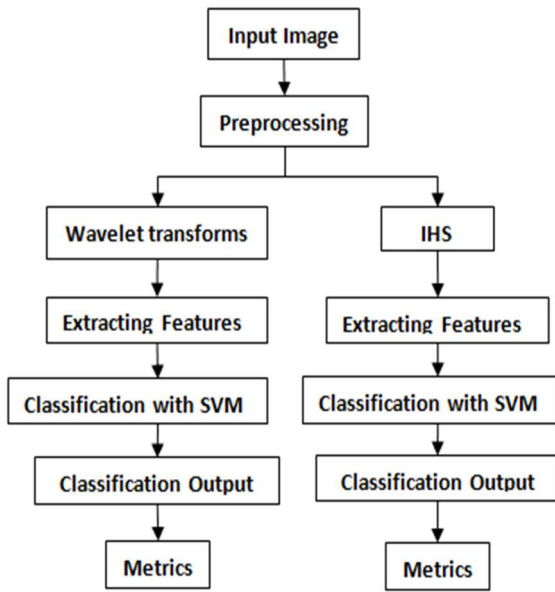

Fig. 2. Block Diagram of Proposed System

A. Wavelet Transform

Around a certain point in time and frequency, wavelets are functions that are concentrated. The shortcomings of the Fourier approach are solved with this transformation technique. The Fourier transformation does not include time information even though it deals with frequencies. We can either have high-frequency resolution and poor temporal resolution, or the opposite, according to Heisenberg's Uncertainty Principle.

The non-desk bound indicators are where this wavelet technique finds its most suitable use. For low-frequency additions, this variant provides great frequency choice, while for high-frequency additives, it produces high temporal resolution. Approximations and information (sub-alerts) are separated into two distinct components using wavelet analysis to separate data shown on an image (alerts).

Filters, high bypass, and sporadic pass filters are used to pass through a signal. The picture is then divided into high-frequency (information) and low-frequency (approximation) components. We receive four sub-alerts for each degree. Due to the horizontal, vertical, and diagonal additions, the approximation displays a typical trend of pixel values and information. If these details are unimportant, they can be treated as zero without having a substantial impact on the image, enabling filtering and compression [23] [2].

B. HIS Transform

One of the most often utilized fusion sharpening procedures is the IHS method. Enhancing colour, features, improving spatial resolution, and combining different data sets has become a typical practice in image analysis. Most of the colour and saturation in the IHS space are spectral reflections. The visual system suggests that an intensity change is easily handled and has no effect on the spectrum's information. The fusion is hence much more suited for therapy in IHS space. In order to assure the spectrum information and add high-resolution detail information, high-resolution and multispectral remote sensing images are fused.

Utilising IHS transformation methods, the RGB values have been transformed [24] [25] [5].

Even though the models complexity vary, they all provide values for hue and saturation. The algorithms' approaches to computing the intensity component of the transformation vary, though. The most typical definitions of intensity are

- V=Maximum {R, G, B}
- I=Average (R,G,B)
- L=Average ([Max(R,G,B) , Min(R,G,B)])

C. SVM Classifier

SVMs, supervised learning methods used for classification, regression, and outlier detection, are classifiers. Machine Learning Classification issues use it most. SVM models represent several classes on a multidimensional hyperplane. SVM repeats hyperplane construction to reduce error. The SVM approach defines the optimum decision boundary or line to split the n-dimensional space into classes, allowing us to quickly categorise fresh data points. Hyperplanes are finest option boundaries. SVMs are used for classification and regression problems in medical signal processing, natural language processing, voice and picture identification, and signal processing. SVM seeks a hyperplane that divides data points into classes. Plus, and minus demonstrate that the "best" hyperplane has the widest margin between the two classes. The slab perpendicular to the hyperplane without inner data points has a margin of its maximum thickness. For linearly separable issues, the strategy maximizes the soft margin, permitting a few misclassifications [26].

By building a one-class SVM whose decision boundary decides whether an item belongs to the "normal" class using an outlier threshold, support vector machines may also be utilized for anomaly detection. Fitcsvm (sample, ones (...), 'Outlier Fraction'...) in this example instructs MATLAB to map all instances to a single class based on the specified fraction of outliers as a parameter. The graph displays the separation hyperplanes for various Outlier Fractions using information from a job of classifying human activities [15] [27].

When data has two categories, apply an SVM. SVMs find the optimum hyperplane that separates all data points in one class from those in the other and classify the data. An SVM's ideal hyperplane has the biggest class difference. The slab perpendicular to the hyperplane without inner data points has a margin of its maximum thickness [2]. The datasets need to be split up into classes before finding a maximum marginal hyperplane (MMH). The next two stages are possible for doing this:

To optimally differentiate the classes, SVM will first iteratively generate hyperplanes. It will then decide which hyperplane best separates the classes. SVMs may categories or regress data that is binary. Computer vision, voice and image recognition, and NLP use support vector machines. A support vector machine optimizes data classification with an ideal hyperplane as the decision surface. Supporting vectors can place the decision surface. Kernel methods include support vector machines (KVMs) [28] [29]. Support vector machines are trained by transforming predictors (input data) to a high-dimensional feature space. The kernel can be

specified with no moving the data to the feature space at this stage. Kernel trick describes this procedure. Solve a quadratic optimization problem to find the best hyperplane to match the data and classify changed features into two groups. Support vector count determines attribute changes [30] [31].

Image fusion is implemented using MATLAB: It merges registered photos of the same object into a single image that may be understood better than the individual images [32] [33]. Creating new pictures that are more suited for human visual perception is the aim of image fusion, particularly in medical imaging.

The MATLAB Image Processing Toolbox includes many reference standards and workflow applications for image processing, analysis, visualisation, and algorithm design [34]. Deep learning and classical image processing can segment, enhance, reduce noise, change geometry, and register images. The toolbox processes arbitrarily large 2D, 3D, and other pictures [9] [25].

IV. EVALUATION METRICS

A. PSNR

By comparing a picture's maximum power to the maximum power of corrupting noise, the peak signal-to-noise ratio (PSNR) gauges how well it may be represented. To establish a picture's PSNR, it is crucial to compare it to an ideal, clean image using the highest amount of power possible. The most widely used technique for determining the efficacy of compressors, filters, etc. is PSNR [35]. With rising PSNR levels supported by the toolkit, the effectiveness of a matched compression or filter technique rises.

$$\text{PSNR}=10\log_{10}\left[\frac{L^2}{\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(O(i,j)-D(i,j))^2}\right] \quad (1)$$

With 0 being the lowest intensity level, L is the total number of possible intensity levels in an image. where O is the matrix data from the original image. D denotes the matrix information of the damaged picture. I is the picture's row's index, and M denotes the number of pixel rows. The letters N and j stand for the number of pixel columns and the position of that column inside the image, respectively[22] [36].

B. Mean square error

Mean Square Error (MSE): Mean square error is an image quality measurement method. The quality is inversely related to the magnitude of RMSE (Root Mean Square Error). The quality of the fused image increases with decreasing RMSE values [37]. The mean squared error, or MSE, is described as follows:

$$\text{MSE}=\frac{1}{MN}\sum_{i=1}^{M}\sum_{j=1}^{N}(O(i,j)-D(i,j))^2 \quad (2)$$

where O stands for the original image's matrix data. D stands for the degraded image's matrix data. I stands for the index of that row of the picture, and M stands for the number of pixel rows. N stands for the number of pixel columns, and j for the index of that column inside the picture [38] [39].

C. Mean square error

The structural measure of similarity (SSIM): It is used to predict how well viewers would react to digital television, motion pictures, and other forms of digital imagery. With the help of SSIM, you may determine how similar two photos are

to one another. In other words, the evaluation or prediction of image quality depends on a starting point that is uncompressed or distortion-free. The SSIM index serves as an exhaustive reference metric [39] [40]. The SSIM index is calculated on different image windows. When two windows are NxN in size, their separation is as follows:

$$\text{SSIM}(x,y)=\frac{(2\mu_x\mu_y+c_1)(2\sigma_{xy}+c_2)}{(\mu_x^2+\mu_y^2+c_1)(\sigma_x^2+\sigma_y^2+c_2)} \quad (3)$$

V. RESULTS AND DISCUSSIONS

Image fusion is a technology that improves the image quality, reduces the amount of uncertainty, and eliminates any redundant information, making it much easier to diagnose medical conditions. The technique of image fusion involves combining multiple input images into a single output image. This single output image has the capability of representing an image with a higher level of precision than the majority of the other input photos on their own. Fig. 3(a) and Fig. 4(a) are input MRI images which will highlight clear information about soft tissues in the Honeycomb affected lung and IPF lung whereas Fig. 3(b) and Fig. 4(b) are input images of Honeycomb and IPF lung in CT. This CT scan can elevate the inflammations in lung. These two input images are combined for an efficient image conversion for better diagnosis of the disease. These images are applied with fusion techniques such as wavelet and HIS sharpening by using SVM classifier and the obtained output images are shown in Fig. 3(c) and Fig. 4(c) for HIS sharpening and Fig. 3(d) and Fig. 4(d) indicate output images for wavelet transform.
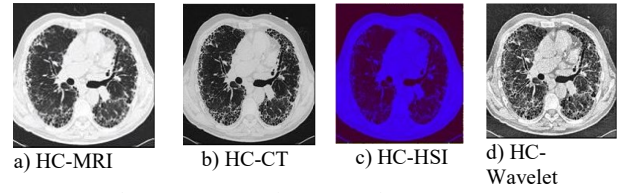

a) HC-MRI   b) HC-CT   c) HC-HSI   d) HC-Wavelet

Fig. 3. Input and Output Images of Honeycomb.

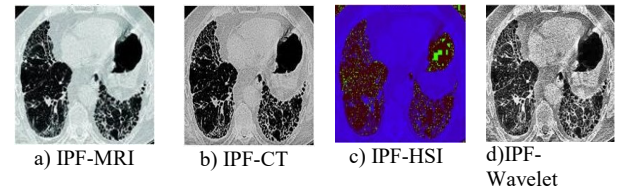a) IPF-MRI   b) IPF-CT   c) IPF-HSI   d)IPF-Wavelet

Fig. 4. Input and Output Images of IPF.

The performance of the techniques is evaluated by different evaluation parameters such as MSE(mean square error), PSNR(peak signal to noise ratio) and SSIM (Structural similarity index measure). These parameters will justify the best suitable approach to extract the anomalism in the lung with Honeycomb pattern and IPF. Fig 5 and 6 exhibits the values of the techniques and these values are compared for both the techniques. The comparison of the techniques is shown the Table I.

Table I.   Metric values of Honeycomb and IPF image

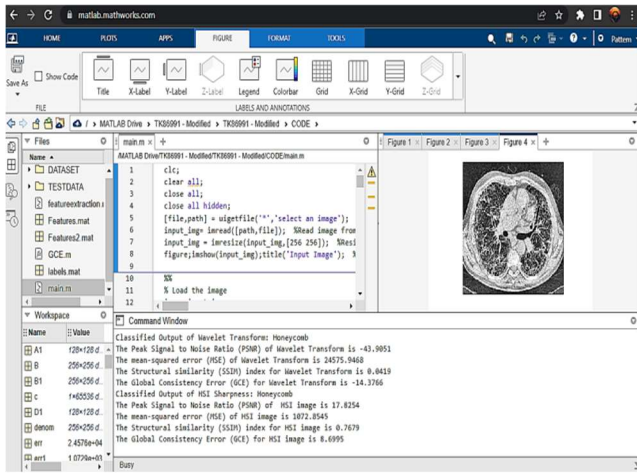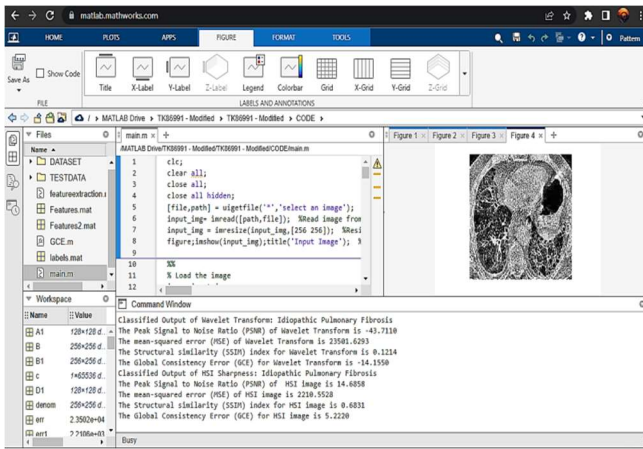|	IPF		Honeycomb	
	Wavelet	**HSI**	**Wavelet**	**HSI**
PSNR	-43.9620	16.2773	-43.7934	17.0737
MSE	24899.913	1525.290	23952.121	1275.584
SSIM	0.0972	0.7806	0.1250	0.7512

Fig. 5. Metric values of Honeycomb image

Fig. 6. Metric values of IPF image

VI. CONCLUSION

Images of Honeycomb and IPF ILDs are taken as inputs and are applied wavelet transformation and HIS sharpening image fusion techniques. By applying the SVM classifier, the extracted features are classified and predicted the disease. And calculate metric values like MSE, SSIM, and PSNR of input and output images. This concluded that the HIS image sharpening techniques give better prediction and accuracy metric values than Wavelet transform.

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