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Detection of Non–Alcoholic Fatty Liver Disease Using Infrared ThermalCamera

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Abstract
Non-alcoholic fatty liver disease (NAFLD), characterized by fat accumulation in the liver is linked to metabolic factors. The limitations of liver biopsy necessitate non-invasive diagnostic methods. This study explores the potential of infrared thermal imaging in screening the NAFLD. Individuals with and without NAFLD underwent thermal imaging. Our work illustrates the effectiveness of this approach by employing the FLIR C3 camera for detailed thermal image capture and analysis. The skewness value of the control group ranged from +5 to -5, indicating a symmetrical distribution of thermal data. In contrast, the NAFLD group showed a skewness of -0.4589, suggesting an asymmetrical distribution. However, the kurtosis valueof the NAFLD group was 0.2044, which was within the range of +3 to -3, similar to the control group. This indicates comparable levels of data concentration around the average temperature in both groups. This study suggests the potential of this non-invasive approach for detecting NAFLD. This could be a suitable adjunct tool to the invasive method of liver biopsy**.**
Keywords— Non-alcoholic fatty liver disease (NAFLD), Infrared thermal imaging, Inflammation, Skin temperature, Biopsy.

Introduction
The sophisticated techniques are difficult in the early screening of Non-Alcoholic Fatty Liver Disease (NAFLD). Thermal imaging is a non-invasive method for evaluating liver health by recording and interpreting the thermal patterns of the skin surface underlying the liver region. The purpose of this work is to investigate the potential of infrared thermal imaging as a screening method for identifying NAFLD. Furthermore, utilizing thermal imaging data, we suggest a unique method that makes use of artificial intelligence (AI)algorithms to improve the precision and effectiveness ofNAFLD detection. It is distinguished by an excessive buildup of fat in the liver cells that is not brought on by binge drinking. As of 2022, the prevalence of non-alcoholic fatty liver disease (NAFLD) among adults in India has been reported to range between 6.7% and 55.1%. Among the
individuals with asymptomatic elevation of liver enzymes, NAFLD cases are frequently observed. Data indicates thatthe prevalence of pre-diabetes, diabetes, and metabolic syndrome among adults in India stands at approximately 19-22% and 15-19% [1].

Liver function tests, medical imaging, and occasional liverbiopsies are integral in diagnosing and monitoring NAFLD. Early detection of NAFLD is essential for initiating timely treatments and preventing its progression to severe stages like steatohepatitis, advanced fibrosis, hepatocellular carcinoma, and cirrhosis. The diagnostic tools including liver function tests and various medical imaging techniques such as CT scans, magnetic resonance imaging, ultrasound, and transient elastography play a vital role in identifying and tracking liver diseases [2].

Even with these well-established diagnostic techniques, liver biopsies remain the gold standard for determining the course of the disease. Additional health hazards are introduced when routine follow-up operations frequently rely on invasive procedures. There is a growing interest in investigating the potential of medical infrared thermal imaging (MITI) as a non-invasive, economical, andpre-diagnostic strategy in addition to traditional diagnostictechniques. However, it is important to recognize that MITIis still a relatively new technology and has not reached the same degree of standardization as traditional medical imaging techniques. Our goal is to aid in advancing, reliability and ease of acquisition to facilitate the timely identification and treatment of NAFLD.

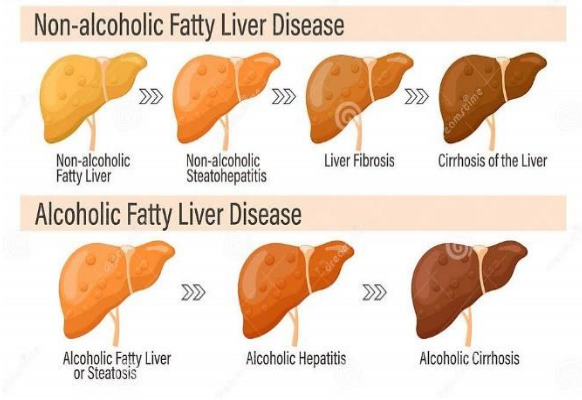

Fig.1 Types of Fatty Liver

I. Literature Survey

Ahmed et al., (2021), Brown Adipose Tissue Activity is Associated with NAFLD and alterations in the gut microbiota, Study among adults shows lower brown fat activity (BAT) linked to more liver fat andhigher blood sugar, regardless of age, sex, and overall body fat [3]. This suggests activating BAT could treat fatty liverdisease, but gut bacteria seem unrelated.

Ikejima et al., (2020) authored a comprehensive titled "Non-alcoholic Fatty Liver Disease/Non-alcoholic Steatohepatitis", Imaging tools spot liver fat and stiffness [4]. Both Magnetic Resonance Elastography and Vibration-Controlled Transient Elastography are imaging techniques used in the diagnosis and assessment of non-alcoholic fatty liver disease (NAFLD), a condition characterized by the accumulation of fat in the liver.

Piscaglia et al., (2020) multi-center observational prospective study on hepatocellular carcinoma (HCC) in Non-Alcoholic Fatty Liver Disease. Researchers are testing combining immunotherapy with existing HCC treatments. Thisapproach could significantly improve the outcomes for patients with all stages of HCC [5]. It might reduce recurrence after treatment for early stages and shrink intermediate tumors, making curative options possible.

Jennison et al.,(2019) discuss the growing health concern of NAFLD. Multiple drugs like obeticholic Acid and elafibranor are in final testing for NAFLD [6]. These drugswork in various ways to improve liver function and reduce inflammation/scarring (fibrosis). While some side effects exist, these drugs offer promise for NAFLD treatment.

II. Methodology

Image acquisition: The efficacy of utilizing the FLIR C3 camera for comprehensive thermal image analysis aimed at detecting NAFLD is demonstrated in this study. The process of obtaining infrared images of the liver region using a thermal imaging camera to obtain precise data is imperative for conducting thorough analysis and achieving high diagnostic accuracy. To guarantee consistency between imaging sessions and reduce variability in the obtained images, standardized lighting and location are crucial [7]. Regular illumination minimizes artifacts and interference that could degrade the image quality. Researchers can improve the repeatability and reliability of their findings by following established processes when acquiring images.

Image Processing: The quality of thermal images obtained from the liver region can only be improved by completing the second step, image preprocessing. To ensure reliable data analysis, methods like normalization, contrast enhancement, and noise reduction are used. Normalization standardizes images for consistency across datasets, contrast enhancement enhances feature visibility, and noise reduction removes undesired disruptions. This sets up the thermal pictures for precise feature extraction and model building to efficientlyidentify NAFLD.

Feature Extraction: Utilizing infrared thermal imaging for the identification of non-alcoholic fatty liver disease (NAFLD) necessitates a meticulous process of feature extraction, whereby relevant data is extracted from thermal images to discern key characteristics indicative of liver health. This process involves employing various techniques such as shape analysis and temperature distribution analysis to pinpoint specific thermal patterns associated with NAFLD pathology. For instance, shape analysis may focus on the contours and structural features of the liver region within thermal images, while temperature distribution analysis delves into the spatial distribution of thermal gradients across the liver surface. These identified characteristics serve as crucial markers for distinguishing between liver tissues in good condition and those affected by disease, facilitating the accurate diagnosis of NAFLD. By extracting these pertinent features, precise models can be developed to effectively differentiate between healthy and diseased liver tissues based on their thermal signatures. This enables clinicians to discern subtle thermal variations indicative of NAFLD with a high degree of accuracy, enhancing diagnostic capabilities.

Model Development: The model development process involves preparing thermal images, extracting key features like skewness and edge detection, and selecting a suitable predictive model. Notably, considerations include data quality, interpretability, and real-world applicability in healthcare settings. The model's ability to generalize across diverse patient groups and imaging conditions is crucial for reliability. Ultimately, it offers a valuable non-invasive tool for early liver disease detection. Future research may aim to enhance interpretability, scalability, and integration into clinical workflows.

Validation and Evaluation: Validation and evaluation are essential steps in assessing the reliability and effectiveness of our proposed thermal image analysis methodology for non-alcoholic fatty liver disease (NAFLD) detection. During validation, we aim to ensure the robustness and generalizability of our algorithm by testing it on independent datasets. Evaluation involves assessing the algorithm's performance using various qualitative and quantitative measures. These measures include visual inspection of the results, comparison with ground truth annotations where available, and feedback from domain experts. Additionally, we employ techniques like cross-validation to verify the consistency of our algorithm's performance across different datasets. Through rigorous validation and evaluation, we seek to demonstrate the practical utility and reliability of our thermal image analysis approach for NAFLD detection.

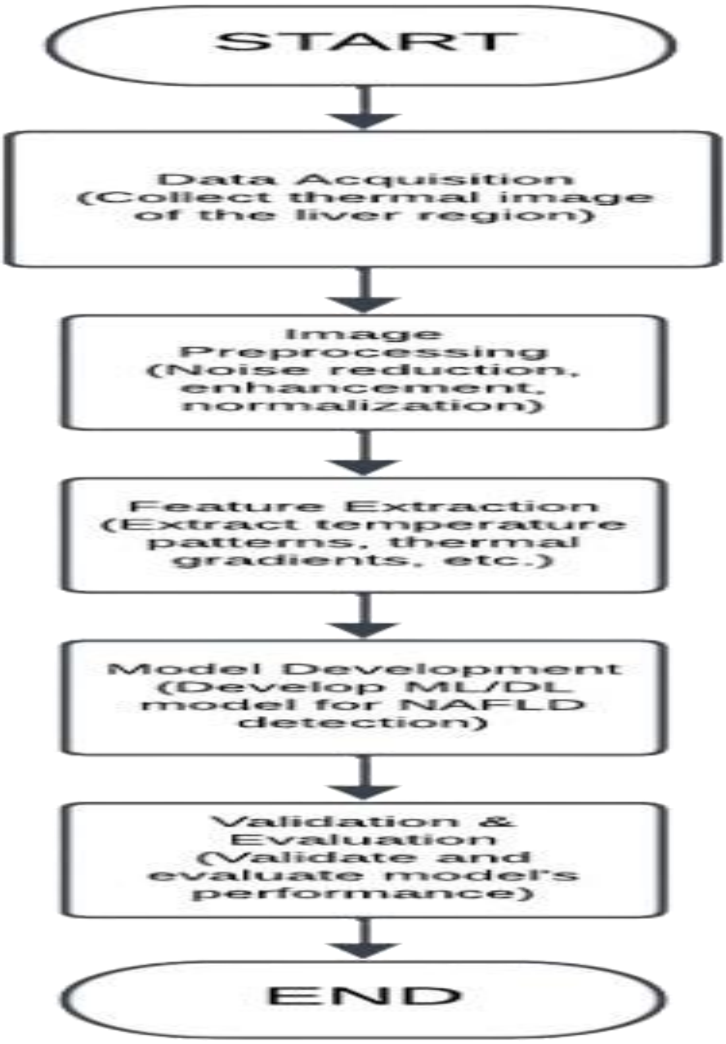

Fig.2 Methodology for the detection of NAFLD

Iv. Results And Discussions

The present study demonstrates the potential of infrared thermal imaging for precise NAFLD detection. The pixel intensity distribution is understood by examining the skewness and kurtosis of the liver region of interest (ROI) in thermal imaging. Determining threshold values for skewness and kurtosis facilitates binary classification, which helps identify traits associated with non-alcoholic fatty liver disease. To precisely identify these thresholds, however, collaboration with medical professionals is essential. To guarantee a trustworthy diagnosis, a thorough evaluation of liver health should also incorporate additional diagnostic techniques and expert advice.

Moreover, this research highlights the non-invasive and economical characteristics of infrared thermal imaging, establishing itas a useful instrument for the prompt diagnosis and surveillance of non-alcoholic fast-fatty liver disease. This method has the potential to improve the diagnosis and treatment of non-alcoholic fatty liver disease (NAFLD) and save healthcare costs by offering insights into liver function through thermal analysis. Our goal is to help patients and healthcare systems globally by contributing to the development of diagnostic methods for liver disordersas we continue to hone and validate our approaches.

In our study, we focused on utilizing thermal imaging techniques to detect NAFLD. Thermal imaging has been widely explored in various medical applications such as breast screening and monitoring conditions like inflammatory arthritis and diabetes [8], this research specifically aimed to investigate its potential in NAFLD detection. We introduced an innovative modification to the calculation methodology of the grey-level co-occurrence matrix (GLCM), concentrating solely on pixels within the ROI of the skin surface underlying the liver region. This adjustment aimed to enhance the performance by eliminating irrelevant information from the analysis. Moreover, this research explored various combinations of feature extraction methods striving to identify the most effective approach for NAFLD classification. These findings not only advance thermal imaging techniques in medical diagnostics but also pave the way for future research directions, such as refining pre-processing techniques and assessing additional feature selection methods tailored specifically for NAFLD detection in human subjects.

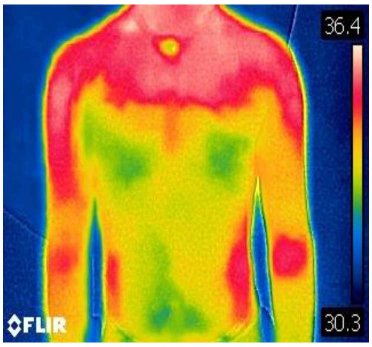

Fig.3 Thermal image of the abdominal region

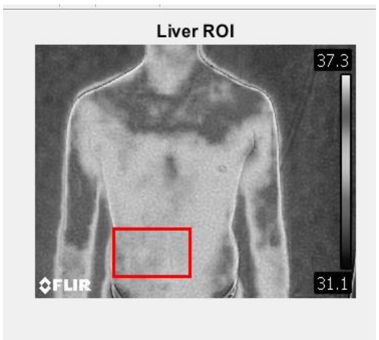

Fig.4 Region of interest of the liver

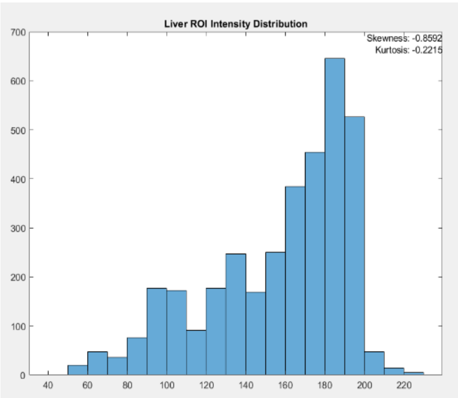

Fig.5 Intensity Distribution of the liver

GENDER	MEAN	MEDIAN	MODE	SKEWNESS	KURTOSIS
MALE	158	168	186	-1.24	0.75
MALE	144	140	133	0.13	-0.31
MALE	157	155	134	-0.27	-0.37
MALE	166	180	188	-0.95	-0.36
MALE	190	191	190	-1.42	4.77
MALE	152	171	181	-0.52	-1.41
MALE	131	124	121	1.28	0.81
MALE	157	175	192	-0.59	-1.30
MALE	150	149	140	-0.13	-0.54
MALE	114	100	93	1.21	0.06
MALE	174	176	175	-0.80	1.17
MALE	158	168	186	-1.24	0.75
MALE	157	175	192	-0.95	0.12
MALE	156	168	190	-0.86	-0.22
MALE	151	160	173	-0.51	-8.54

Table 1 Characteristics of study subjects gray-level
co-occurrence matrix

When examining the values in the above Fig.5, a kurtosis value of 4.770 stands out as an outlier compared to the normal range observed in other individuals. Typically, kurtosis values in a normal population distribution range between -3 and +3. However, this exceptional value indicates a significant deviation from the expected distribution, suggesting a potential anomaly in thermal patterns associated with liver health. Such deviations could signify underlying liver abnormalities or pathology, warranting further investigation and potentially diagnostic interventions [9]. Therefore, the individual exhibiting this elevated kurtosis value may require closer monitoring, additional diagnostic tests, or medical consultation to determine the underlying cause and appropriate course of action. This emphasizes the importance of integrating statistical analysis, such as kurtosis assessment, into thermal imaging-based diagnostic protocols for NAFLD screening and management.

V. Conclusion

This present research outlines a method for non-invasive detection of NAFLD usinginfrared thermal imaging. Skewness and Kurtosis calculations provide insights into the distribution of thermal patterns associated with liver health. Subsequently, we identify the liver region of interest (ROI) and conduct intensity distribution analysis using a histogram to understand further thermal characteristics linked with NAFLD. while our method shows promise in NAFLD detection, there are opportunities for refinement and future implementation. Improving the accuracy and robustness of feature extraction algorithms could enhance the characterization of thermal patterns associated with NAFLD, thereby improving diagnostic accuracy. Exploring machine learning techniques for predictive modeling may also augment the sensitivity and specificity of our detection method, leading to more reliable clinical outcomes. Additionally, validating the efficacy of our approach across diverse patient populations and integrating it into routine clinical practice is essential. By continually refining and advancing our methodology, we can realize its full potential as a valuable tool for early detection and management of NAFLD, ultimately improving patient outcomes and healthcare delivery.

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