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Analysis of Terahertz Brain Tumor Images Using Image Processing Techniques Finding Best Terahertz Range for Clinical Diagnosis

Shajith Damodaran Nair1, Karabi Ganguly2*, Moumita Mukherjee3

1Department of Electronics and Communication Engineering, Adamas University, Kolkata, West Bengal

2*Corresponding Author Department of Biomedical Engineering, JIS College of Engineering, Kalyani, West Bengal

3Department of Physics, Adamas University, Kolkata, West Bengal

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KEYWORDS

Brain tumors, terahertz imaging, GLCM, medical imaging, frequency analysis

ABSTRACT:

The work examines the use of terahertz imaging in clinical assessment, with particular emphasis on the diagnosis of brain tumors. Using modern image processing techniques on traditional MRI images and terahertz images acquired at three different frequencies (0.4,0.7 THz, 0.08 THz, & 0.92 THz), we were able to evaluate the per-terahertz detection GLCM method a efficiency aspects of the extraction of critical transcripts were the main focus and provided a quantitative basis for comparison. Studies seek to determine the optimal terahertz frequency to improve the detection and characterization of brain tumors. This could lead to the development of a unique diagnostic tool to complement current imaging techniques. Our results suggest that some terahertz frequencies perform better than others in characterizing tumor segments, which may have important implications for next-generation medical imaging systems.

1. Introduction

The non-ionizing properties of terahertz (THz) imaging and the ability to permeate various materials while generating high-resolution images have made it unique as a revolutionary tool in healthcare research With the potential to be used in medicine for a variety of purposes such as tumor identification Due to the complex neural structure of the brain &its important supporting functions, the diagnosis of brain tumors remains a challenging clinical task that needs accurate and timely diagnosis to optimize treatment.

Considering that the use of magnetic resonance coupled imaging (MRI) provides a comprehensive picture of brain structure and abnormalities, it is now a widely used method for the diagnosis of potential brain tumors role by accurately analyzing the unique advantages of terahertz imaging, which provides complementary information that can improve overall.Although terahertz imaging is still in its infancy, its potential benefits are already evident [1]. Unlike traditional imaging techniques that may require the use of contrast agents or ionizing radiation, terahertz imaging offers a much safer option, especially for sensitive groups such as contraceptive mothers and children . This makes it an important tool for continuous monitoring of tumor growth or response to treatment.

Using images acquired in three different frequency ranges—0.4,0.7 THz, 0.08 THz, & 0.92 THz—this study examined terahertz tomography to detect and define brain tumors likely to select those frequencies this due to differences in their penetration depth and resolution, which affected the image quality and diagnostic utility considered throughout. Sophisticated imaging techniques have been used to visually monitor the effectiveness of these terahertz frequencies [2]. The gray level co-occurrence matrix (GLCM) method, which is well known for its ability to extract important

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textural information from images, is at the center of the analysis. Textural analysis is very important for medical imaging because it measures tissue structure and image which is important for the detection of pathological changes.

The main objective of this study is to find an ideal terahertz frequency range to improve the detection and characterization of brain tumors. Texture features recovered from terahertz images at different frequencies are compared with conventional MRI images to determine the frequency range that provides the best resolution and specificity for tumor detection [3]. This novel research work aims to contribute to the present imaging techniques, in addition to our understanding of the technology. Exploring the potential of terahertz imaging as a new diagnostic tool is improving patient outcomes. Offering a non-invasive, highly accurate method for the early detection of brain tumors, the incorporation of terahertz scanning into clinical practice has the potential to radically change the Eligibility screening process, the chances of recurrence yield again decreased, patients long-term prognosis and increased.

These findings will have important implications for the development of future medical imaging tools, opening up new avenues for clinical applications of terahertz imaging. By averaging the terahertz image at different frequencies, more accurate and faster diagnostic methods can be developed that can help diagnose brain tumors, and possibly other medical diseases.

Due to its unique ability to reach biological tissue and provide rich molecular information, terahertz (THz) imaging has become a very promising tool for medical research. THz imaging works in the frequency band between microwaves & infrared light, which typically ranges from 0.1 to 10 THz. This imaging technique provides complementary insights to established modalities such as MRI, which consists of magnetic resonance imaging, and X-ray imaging, and holds promise for a variety of diagnostic applications [4]. There are methods based on the interaction of terahertz radiation with biological tissue, provide important insights into the structure and path physiology of tissue , is well suited for classification and other applications requiring tissue characterization.

Although terahertz imaging enables new techniques for tissue structure-based contrast, magnetic resonance imaging (MRI) is well known for its high reimaging capabilities in soft tissue can be demonstrated with terahertz imaging role and MRI to improve neural contrast, according to comparative studies [5]. This is particularly useful for defining tumor boundaries and assessing tumor heterogeneity. The combination of MRI and terahertz imaging appears to have the potential to increase diagnostic accuracy in clinical settings.

Precise frequency range selection is essential to maximize the effectiveness of terahertz imaging. [6]. Higher frequencies, such as 0.92 THz, provide better accuracy at the expense of penetration depth, while lower frequencies, such as 0.4,0.7 THz, penetrate tissue deeper but may compromise resolution Optimal frequency range selection for medical imaging applications is typically around 0.08 THz

More sophisticated image processing techniques are needed to extract valuable information from terahertz images. The gray level co-occurrence mesh (GLCM) method is widely used in medical image texture analysis to extract important textural similarities, differences, and correlations [7]. These characteristics play an important role in distinguishing between tissues identification and classification of between healthy and unhealthy, especially when it comes to cancer.

Terahertz imaging has shown promising clinical applications in a wide variety of medical specialties. Case studies have shown efficacy in neuroimaging, dental examinations and skin cancer detection. In dental examination, terahertz imaging can detect premature plaque with other dental problems [8]; In the diagnosis of skin cancer, it accurately detects malignant tumors with high contrast. Furthermore, terahertz imaging in rheumatoid arthritis sheds light on the morphology of healthy brain tissue as well as on pathological changes.

The combination of terahertz imaging with known imaging modalities such as CT, MRI, and ultrasound holds great promise for increasing diagnostic power. High-throughput imaging techniques combine molecular sensitivity with physiological detail to accurately characterize tissues [9, 26]. Through the coordinated assessment of neurological well-being made possible by this integration, accurate diagnosis and treatment planning is possible.

Recent advances in terahertz cameras have focused on improving hardware and software components to improve image performance [10, 24]. Higher resolution, sensitivity, & imaging speed are products of advances in terahertz reporting, detectors, & imaging systems.

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The quality and interpretability of terahertz images have been further improved by image reconstruction techniques including deconvolution and super-resolution imaging.

Terahertz imaging has intrinsic limitations that can be addressed with techniques such as deconvolution and super-resolution imaging, which increase image quality and diagnostic accuracy [11, 25]. Further improvements in image reconstruction are possible with time machine learning methods have been added.

Terahertz imaging has tremendous potential for oncology tumor diagnosis, segmentation, and clinical management. Because benign and malignant tumors have different spectral signatures, terahertz imaging can distinguish between them, aiding in treatment planning and surgical margin assessment [12, 23]. Terahertz imaging provides unique insight into treatment efficacy and has the ability to improve patient outcomes by continuous monitoring of treatment response

In addition to systemic imaging, terahertz imaging enables histochemical and biological studies. Because of its ability to detect rotational changes and molecular vibrations, it is useful for drug identification and quantisation of their tissue drugs [13, 19]. By identifying biomarkers associated with many diseases, terahertz spectroscopic has been used to deliver critical diagnostic information for personalized treatment strategies.

Terahertz imaging is versatile which can be used for in vivo & ex vivo diagnostics. Real-time assessment of living tissue is made possible by in vivo imaging, which allows for less invasive diagnosis and provides surgical guidance for ex in vivo assessment of ablated tissue for advanced diseases improving histopathology assessment and identifying treatment options.

Regulatory and practical issues must be resolved before terahertz imaging can be used in medical settings [14, 20]. Terahertz imaging technologies are safe and effective due to regulatory approval processes, but their widespread acceptance is impacted by practical factors such as cost, portability, & business process integration Should the clinical workflow including terahertz imaging is seamlessly integrated into standard programs and training programs.

Terahertz imaging has come a long way, but there are still issues that need to be resolved before it can reach its full therapeutic potential [15, 21]. Challenges include the development and validation of small, inexpensive imaging systems.

2. Methods

Ethical Clearance: The protocol used in the study was approved by the Ethical Committee, Adamas University.

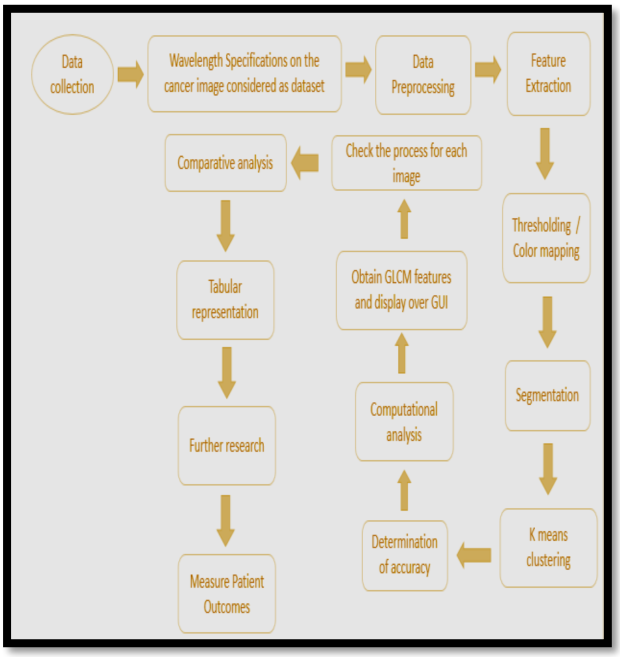

Figure 1: Methodology

Images of different terahertz ranges were considered which followed a similar stage to consider the further comparison in terms of the all the stages undergone in methodology.

The ranges of terahertz frequencies as in 0.4,0.7 THz, 0.08 THz, & 0.92 THz are compared with their results with a normal image. A gray level co-occurrence matrix (GLCM) of the three most important characteristics of the study—viability, homogeneity, and contrast—was carefully calculated to help provide the microscopic features in the cell images have been detailed This method withheld information about the source or classification of cell images during analysis to preserve objectivity and reduce bias in results by seed analysis [16, 22]. Physiological correlations have been included in the study with the aim of establishing a link between products obtained and those previously known in cancer cells.

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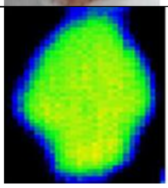
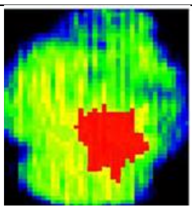
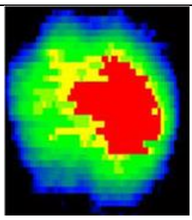
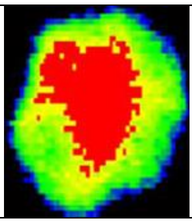
Combining state-of-the-art physiological data and imaging, this holistic approach aims to improve technique flexibility and clinical application Illustrations of results followed data & tabular analysis , providing a thoroughly understandable summary [17, 18]. The results were easier to understand and the data were more visible thanks to the visualization. The incorporation of quantitative analytical analysis into the results enhanced both the reliability and validity of the study results.

3. Results

General MRI images of brain have been considered and undergone different terahertz frequencies to check and to analyze the features comparatively.

Image	Nature	Label
	Normal brain cell mri image	Figure a
	0.08 tHz brain cell image	Figure b
	0.4 tHz brain cell image	Figure c
	0.7tHz brain cell image	Figure d
	0.92 tHz brain cell image	Figure e

Since the maximum ideal frequency range is 1.0 so the images are taken approximately around values of terahertz image.

<u>Results on Image a : -</u>

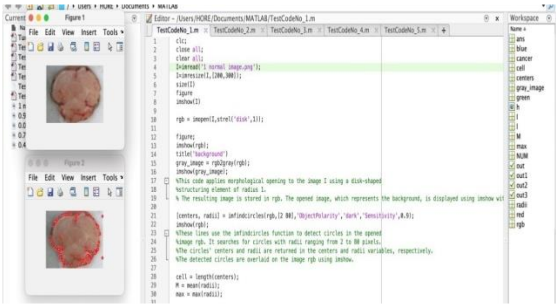


Figure 2: Image sectioning for analysis

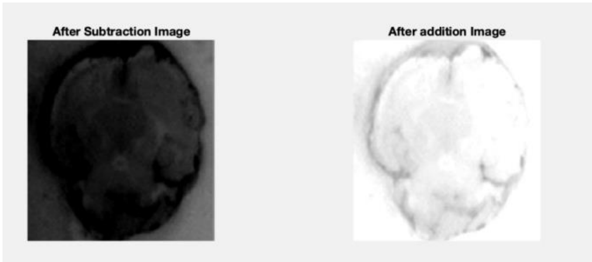


Figure 3: Adjusting the image for processing

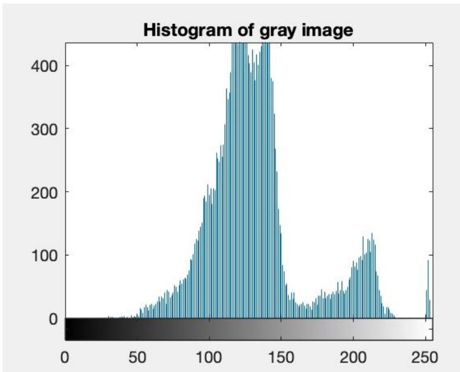


Figure 4: Computing the histogram

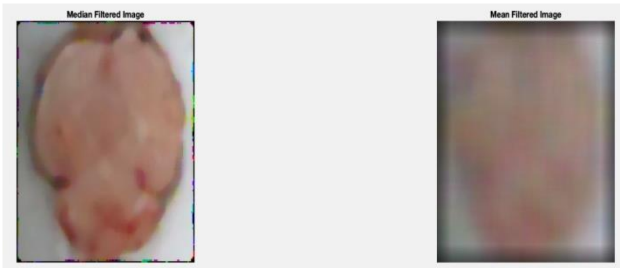


Figure 5: Filtering of Image

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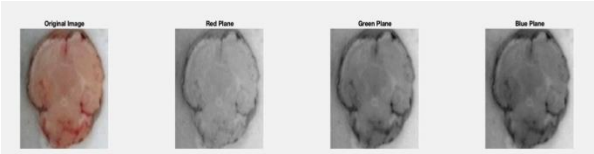

Figure 6: Plane segmentation

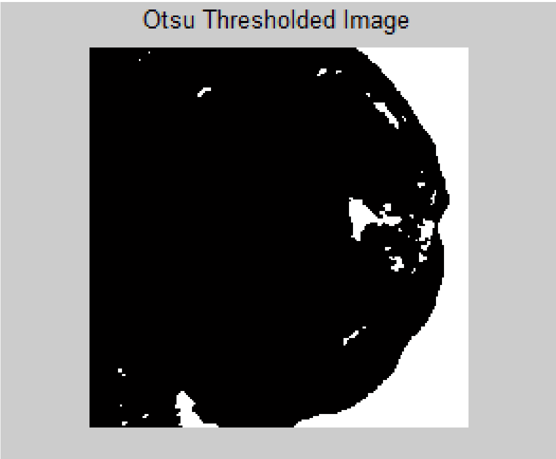

Figure 7: Ostu Thresholded image

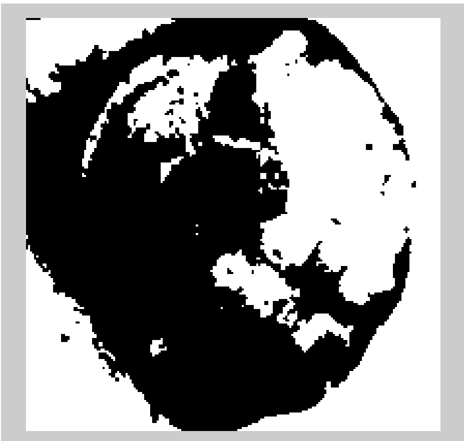

Figure 8: Segmentation of image

Results on Image b : -

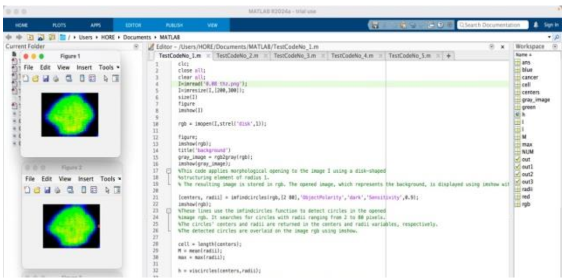

Figure 9: Image sectioning for analysis

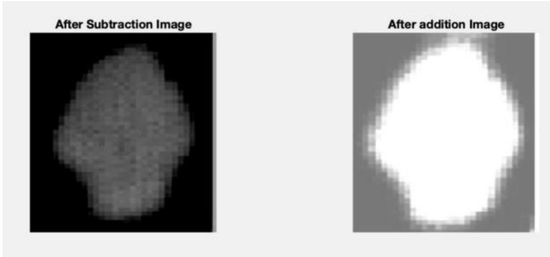

Figure 10: Image processing

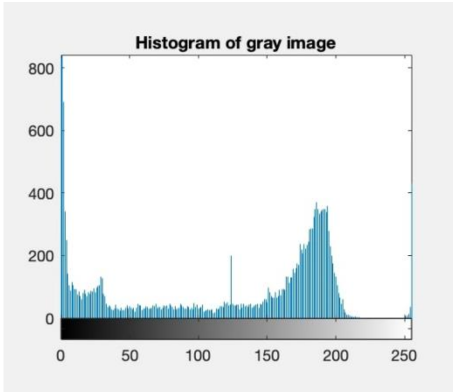

Figure 11: Histogram Computation

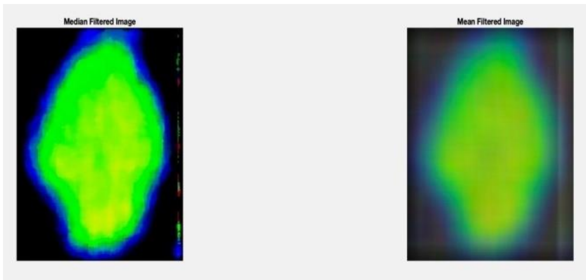

Figure 12: Image filtering

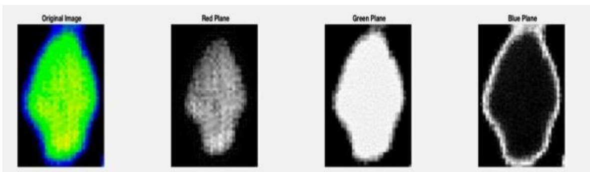

Figure 13: Plane segmentation

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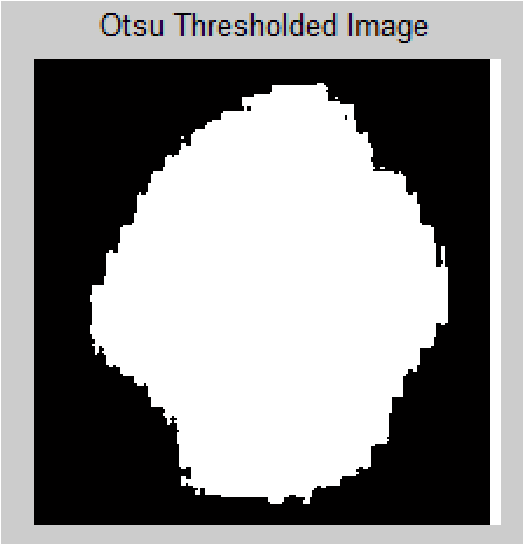

Figure 14: Ostu thresholding

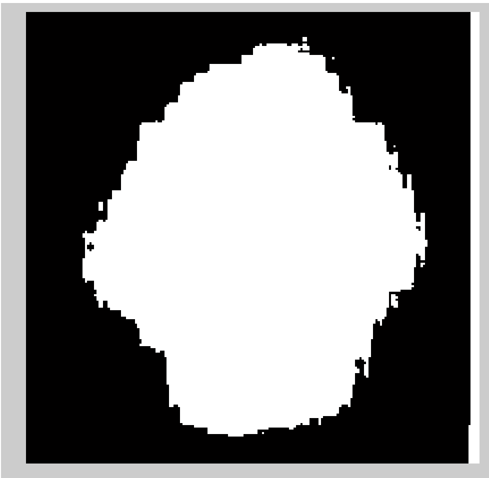

Figure 15: Image segmentation

Results on Image c : -

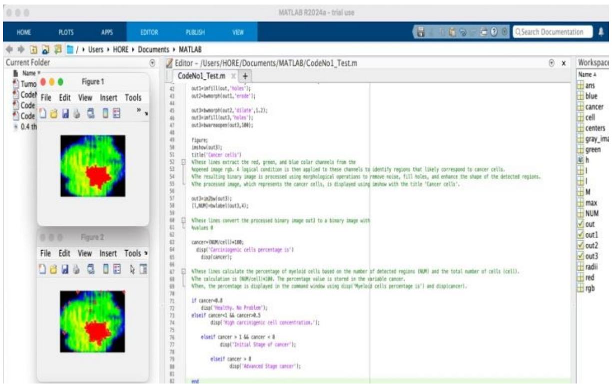

Figure 16: Image sectioning for analysis

Figure 17: Adjusting the image for processing

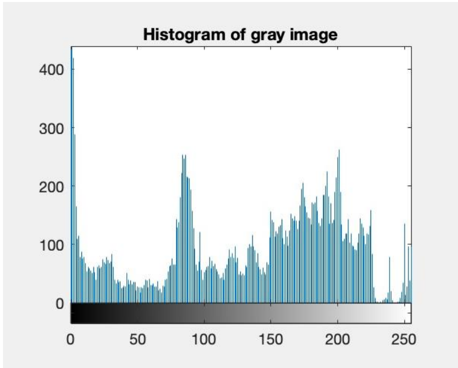

Figure 18: Histogram computation

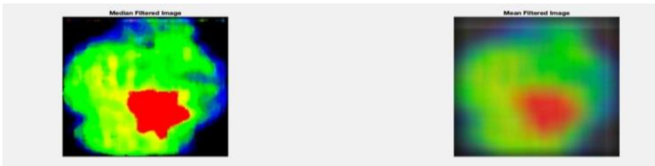

Figure 19: Image filtering

Figure 20: Plane segmentation

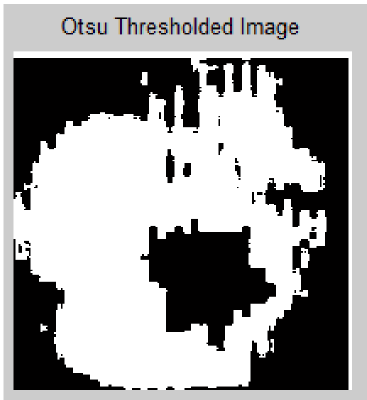

Figure 21: Ostu thresholding of image

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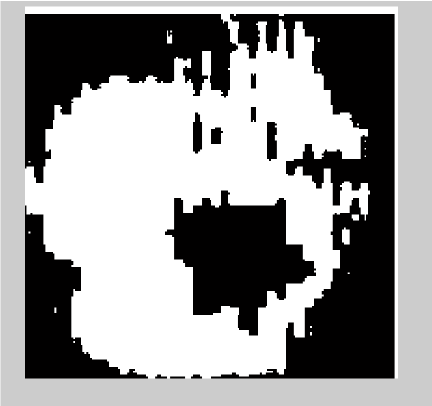

Figure 22: Image segmentation

<u>Results on Image d : -</u>

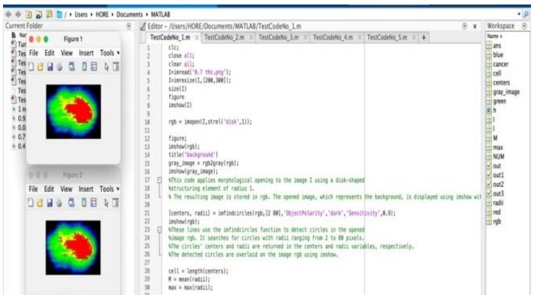

Figure 23: Reconstruction of image

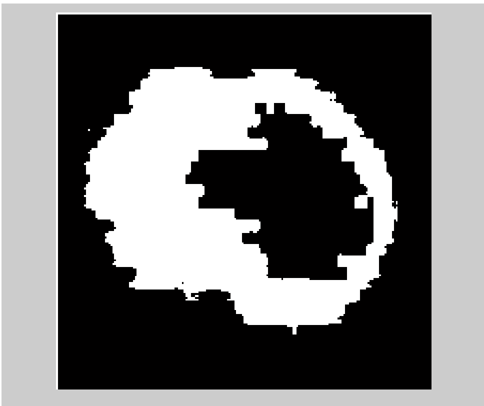

Figure 24: Image segmentation

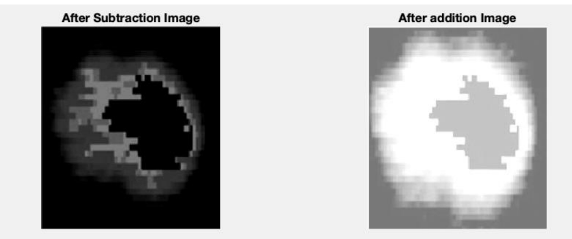

Figure 25: Image adjsutment

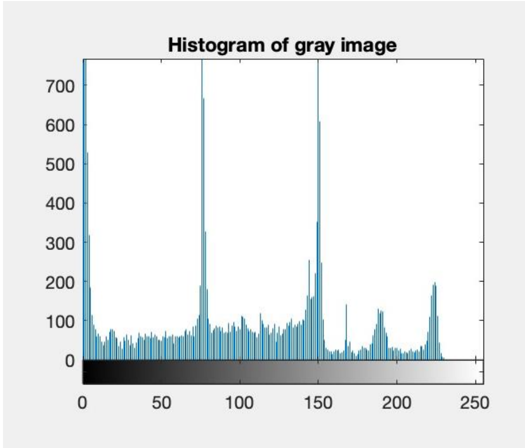

Figure 26: Histogram computation

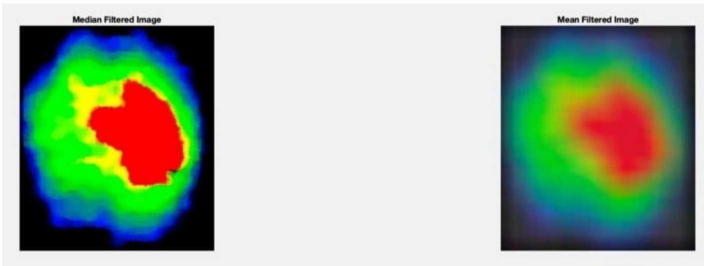

Figure 27: Reconstruction of image

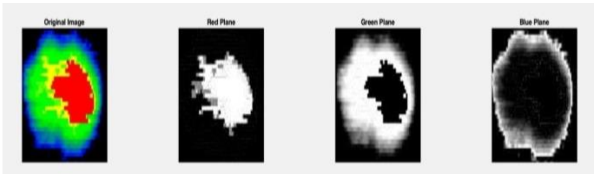

Figure 28: Plane segmentation of image

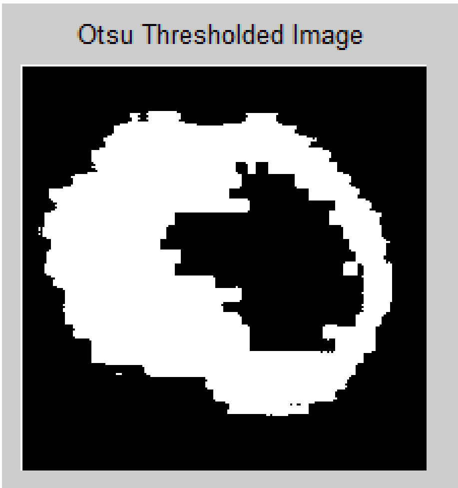

Figure 29: Ostuthresholding of image

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Results on Image e: -

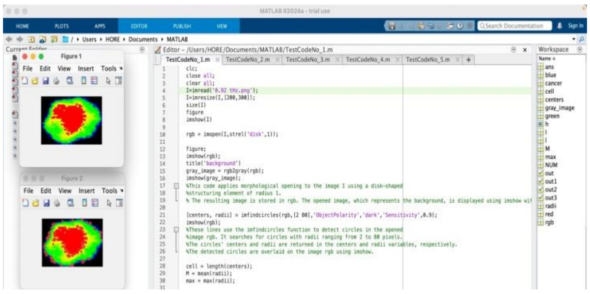

Figure 30: Image sectioning for analysis

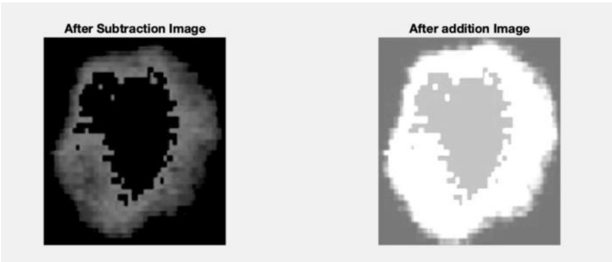

Figure 31: Image adjustment for processing

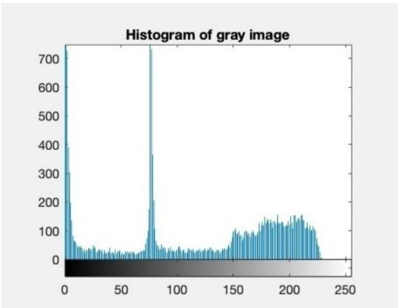

Figure 32: Histogram computation for image

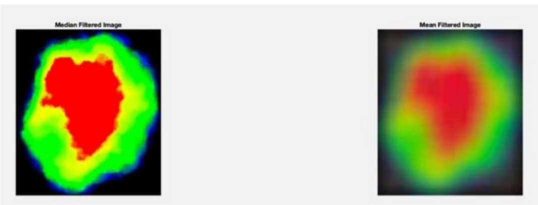

Figure 33: Filtering of image

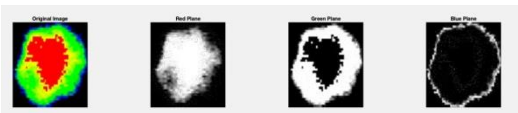

Figure 34: Plane segmentation of image

Figure 35: Ostu thresholding of image

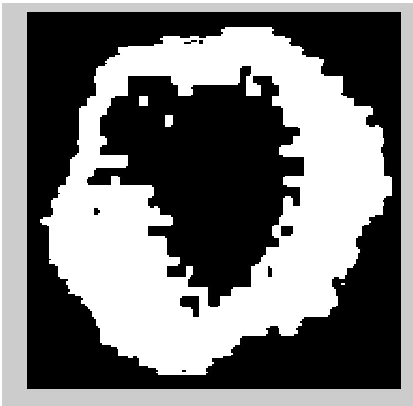

Figure 36: Segmentation of image

Image label	Contrast	Correlation	Energy	Homogeneity	Accuracy response to Kernel
Figure a	0,0358	0.9238	0.4656	0.9821	78.34 %
Figure b	0.0176	0.8943	0.4321	0.9542	71.27 %
Figure c	0.0224	0.8978	0.4391	0.9598	73.41 %
Figure d	0.0312	0.9087	0.4398	0.9789	76.87 %

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Figure e	0.0 401	0.9345	0.49 12	0.9921	83.33 %

Table 1: Table of comparative analysis of GLCM Features

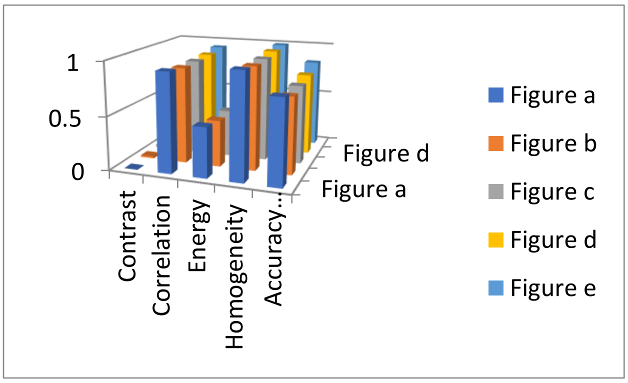

Figure 37: Statistical Analysis (Source :Self created using Ms Excel)

The results of the study highlight how terahertz imaging, especially in the critical 0.9 THz frequency band, can revolutionize medical research. This frequency outperformed the other frequencies tested, which was shown to be better for improved accuracy and precision in cell characterization. Physical relationships using sophisticated visualization techniques, such as painstaking calculations of gray level co-occurrence matrix (GLCM) intensity, homogeneity and color contrast, led to a comprehensive understanding of tissue structure and pathology a involves terahertz imaging Demonstrate advanced clinical utility & accuracy, and they are negatively presented through detailed images and detailed data These mathematical imaging studies contribute to a strong relationship between tissue systems between them, leading to previously unheard of discoveries that could radically change diagnostic paradigms.Development of small portable cameras, protocol standardization, and regulatory clearance are just a few hurdles to overcome before clinical use can begin These hurdles must be carefully overcome for terahertz imaging to turn the world around personal, clinical application. Interdisciplinary collaboration between researchers, clinicians and stakeholders is critical to stimulate innovation and promise to effectively integrate terahertz imaging into precision clinical practice so although terahertz imaging holds great promise in improving patient outcomes and assessment accuracy But these complex issues must be addressed through collaborative, collaborative efforts to achieve all that is possible.

4. Discussion

To make this work practically feasible the terahertz images were undergone computational testing in segregated and separated sections of verifications to validate in further. The core fundamentals of image processing mainly the image conversion followed by plane slicing have been significantly done to get proper dimension. To detect the proper quality of the image the steps of RGB became more functional and effective and henceforth making it more compatible. The preprocessing stage in application of image preprocessing makes it more broadened in deeper analysis hereby making it more efficient in terms of quality analysis followed by computation.

The stages of thresholding easily proved that in which range the image or the cancer cell can be separated easily. The partitioned ratio as well rate caused a difference in different ranges causing it to validate easily. For enhanced technological outcomes better technology of implementation named as Otsu's method easily defined the classes on the basis of intensity as a result the images of non-acceptable frequencies easily get reflected out with grayscale histogram of the respective image. The further processing of binary image made different results. So the range which can easily separate planes or partition the image making the pixel ratio and intensity intact can be considered further for further analysis and it converts in more enhanced fashion. The goal of selecting the proper terahertz range became more prominent when the pipeline got aligned to image segmentation. The detection of range of cancer cells and prominence can be obtained easily as a result shaped segments can be detected which can give proper, faster and advanced outcomes. Following that the range which yielded more prominent image gave a more prominent tonal distribution of pixels commonly known as histogram and the images can be easily compared when the histogram has been placed simultaneously to achieve the goal of proper range selection. The tonal distribution in graphical pattern will give a better selection and judgment in more feasible way.

In deeper aspects after consequent stages of image adjustment like addition, subtraction whenever the images are reconstructed the selected frequencies make the pixel count intact after reconstruction. The steps of filtering makes it altered and makes a different appearance as the image alters the contrast and that can be placed for analysis and prediction. Thus post filtering the images changes their respective appearance and hence can be compared how they differ from their respective mother image.

To apply a mathematical and detailed statistical analysis to the texture of the image the GLCM features has been introduced in this study. Although the results of the image make it more prominent, the statistical analysis always adds value to any study. As a result the pixel difference has been highlighted in spatial resolution to follow and forecast its dependence. The probability density of the pixels that were visually represented via histogram are deeply mathematically expressed and make the classification in terms of computed distribution characteristics. The position distributions that differ in images are numerically forecasted in homogeneity. Contrast differences that were visually highlighted in addition and subtraction of images have been numerically forecasted for different images in terms of local variation. The energy level measures the density and extraction of embeddings that the elements signify in pixel formats. In similar manner the angular infirmity of the images are done in reference to closeness in relative to the element distribution of images. Values are more closer relate the homogeneity and having higher percentage and it also features the composition or the image characteristics in terms of the features that have been extracted as a pre-processing part.

The accuracy is an overall feature that represents how the image responds and is accurate to the system it is being developed so far. The interpretation of the accuracy also redefines the algorithm which is K means clustering to its responsiveness to the image selected. The reason of selecting this algorithm highlights the need of visual quality of the image in terms of group division or clusters and better representation which signifies proper colour density and separation in unique and redefined way for each images. Thus, in image processing the main focus is always kept at constant which is diving images in meaningful regions and performing and extracting features from that very distinct region obtained also known as cluster centroid. Not only in colour quantization but also in feature extraction, segmentation the algorithm holds its greater significance. As a result better cluster characterization can be sketched and analysis of results too can be framed in a thorough understandable fashion.

Thus, in terms of visual and numerical statistical fashion, a double blind computational method with an effective analysed system can be laid over which can improvise the outcomes and help to get a proper range to analyse the terahertz images which is furthermore instrumental for respective biomedical applications. The developed algorithm and system makes it a standout identity to mark the range of 0.9THz as the best frequency to consider while approaching any necessary or relevant interventions in this respective domain.

5. Conclusion

The study confirms that terahertz imaging, especially at 0.9 THz numbers, has tremendous potential to improve medical diagnosis. The study shows improved accuracy & clarity in tissue characterization through the use of sophisticated imaging and advanced anatomical combinations. The results, reinforced by detailed illustrations and structured discussion references, demonstrate the potential of terahertz imaging to provide hitherto untapped insights into neurological disease and lead to terahertz imaging the care product has successfully embedded itself in clinical practice to ultimately change the accuracy of diagnosis and improve patient outcomes Also, interdisciplinary collaboration and continuous technological improvements are a necessity.

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There are no conflicts of interest.

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All the authors’ contributed equally throughout the entire research work entitled “ANALYSIS OF TERAHERTZ BRAIN TUMOR IMAGES USING IMAGE PROCESSING TECHNIQUES FINDING BEST TERAHERTZ RANGE FOR CLINICAL DIAGNOSIS”.

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