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Article Title: Detection of Pancreatic Cancer Using Convolutional Neural Network Classifier

Detection of Pancreatic Cancer Using Convolutional Neural Network Classifier

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ABSTRACT

Early-stage pancreatic cancer is highly curable, although it is uncommon to find. This is because symptoms often don't show up until the disease has spread to other organs. The treatment choices for pancreatic cancer are determined on the extent of the malignancy. Options include surgery, chemotherapy, radiation therapy, or a combination of these. Nevertheless it is are difficult to separate and manually classify because of their small size and hazy boundaries. This study proposes to identify pancreatic cancer by utilizing an optimized convolutional neural network (CNN) classifier. The test image is segmented using the Fuzzy C Means segmentation approach. The Grey Wolf Optimization GWO algorithm is used to optimize the procedure after features are extracted using Gabor based Region Covariance Matrix Method. The result is accurately predicted owing to strong classifier (a GWO-based CNN). The proposed work is implemented using simulation tools from MATLAB.

Keywords: Pancreatic cancer, Gabor based Region Covariance (GRCM), Fuzzy C Means, Grey Wolf Optimization (GWO) and Convolutional Neural Network (CNN).

1 Introduction

Pancreatic cancer has a 9% survival rate because of its late diagnosis and lack of curative treatment options, making it the fourth most common cause of cancer-related fatalities. Radiation, chemotherapy, and surgery are the few standard treatment options available [1].

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Weight loss and jaundice are signs of pancreatic cancer, which is often found in its advanced stages due to its difficulties in identification. The size, location, and absence of metastases from the tumour will all influence the treatment plan, with diabetes mellitus and chemical exposure being risk factors [2]. There are two types of cancer that can arise in the pancreas: exocrine tumours, which account for approximately 93% of all pancreatic tumours, and neuroendocrine tumours, which are the most common type. Adenocarcinomas are the most common type of pancreatic cancer, starts at the pancreatic ducts and is often misdiagnosed as pancreatic cancer [3]. The remaining pancreatic tumours, or around 7% of the total, are neuroendocrine tumours (NETs), often referred to as pancreatic NETs (PNETs), islet cell tumours, or islet cell carcinoma. Certain NETs produce extra hormones might depend on the hormone the cell produces an insulinoma, for instance, is a tumour in an insulin-producing cell [4]. As per the American Cancer Society, pancreatic cancer accounts for roughly 3% of all cancer cases and 7% of all cancer-related fatalities in the US. Men are somewhat more likely than women to experience it [5]. Oncologists use a variety of tests to diagnose pancreatic cancer in order to establish the patient's level of disease progression and identify the illness's presence. These examinations include, among others, blood tests, cholangiopancreatography, ultrasound, computed tomography (CT) scans, magnetic resonance imaging (MRI), and PET/PET scans [6]. The Wiener filter in preprocessing techniques is used to address issues that the filter previously discussed was unable to resolve. It removes extra noise and switches the blurring all at once. The Wiener filter yields a linear approximation of the source image [7]. Otsu's method is one of the best for image thresholding due to its simple calculation; nevertheless, if the histogram became non-bimodal, segmentation problems can happen. Choosing the number of cluster centers is crucial for the learning process, even if K-means works best when the data set is distinct [8]. Linear discriminant analysis (LDA) is a simple, effective, and portable methodology. The Principal Component Analysis (PCA) method is introduced to address the issue of overfitting data by minimizing the number of features. Using the GLCM feature extraction approach can significantly reduce the amount of time needed to compress images while converting RGB to grayscale when compared to traditional DWT procedures [9]. The SVM approach requires payment for a five-fold cross-validation process in order to generate probability estimates; it does not do so instantly. This leads to the explanation of Artificial Neural Networks (ANN), a very computationally intensive soft computing technique. Using CNN classifier, which can identify important features without human intervention and offers incredibly high accuracy in photo identification tasks, is one way to address this problem [10]. To increase the chance of survival and find pancreatic cancer early. In order to reduce noise in an image, Wiener filters are utilized during the pre-processing stage. Fuzzy C is then used for picture segmentation. To significantly extract the features, GRCM is utilized. CNN with optimal tuning by GWO is designed for classification performance. The list below demonstrates how the paper is organised: Section I gives a description of the introduction. The

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recent works are described in Section II. The proposed model and description are explained in Part III. The results are presented in Section IV. In Section V, the conclusion is presented.

2 Recent Works

D. Agarwal *et al* [2022] [11] have proposed the effectiveness of traditional multi-class classification methods can be enhanced by combining suitable feature engineering techniques with a Hard Hierarchical Decision Structure (HDS). These frameworks overcome the shortcomings of past research that depended on basic biostatistical techniques and underutilized the data produced by ultrasensitive protease/argininease analyses. An early-stage pancreatic cancer diagnosis is modelled as a multi-class classification task. Additionally, to offer anticipated label confidences in the form of class probability values, a Soft Hierarchical Decision Structure (SDS) is built.

Y. Li *et al* [2021] [12] have presented a safe and precise PDT optical fiber deployment for pancreatic tumor treatment is now feasible because to a novel soft robot laparoscope design. Due to its potential to treat cancer non-invasively by light exposure, photodynamic therapy, or PDT, has recently attracted more interest. Since light penetrates the tissue only to a depth of less than 1 cm, the PDT optical fiber must usually be positioned close to the malignant location in order to achieve the desired therapy effect. The suggested soft robot has the ability to move in three directions (DoF): axially, in-plane, and linearly. Robot forward kinematics model was constructed by means of a generalized calibration method, whereas differential kinematics was derived analytically.

Y. Wang *et al* [2021] [13] have presented a local instance level classifier for semi-supervised PDAC segmentation and a global image-level classifier for normal/PDAC segmentation using an Inductive Attention Guidance (IAG) technique that benefits from linking the MIL-based global and local classifiers. A developing trend in deep learning is the prediction of cancers such as PDACs from medical images, including both classification and segmentation. However, this requires a huge amount of annotated data for training, which is labour-intensive and time-consuming.

Z. Chen *et al* [2018] [14] have presented saline solutions and plasma to treat human normal and pancreatic cancer cells utilizing a range of Self Organization Patterns (SOPs). We have seen several self-organized patterns that have developed at the liquid's surface. Using UV-visible-NIR optical emission spectroscopy, the spectra of plasma with SOPs were described. Saline solution is injected intravenously to treat dehydration and is also used to dilute injection-based drugs. The SOP plasma-activated saline solution may be used as an oral medication or as a treatment that can be injected into tumors, according to the results.

C. Li *et al* [2018] [15] have provided numerous helpful hub genes for upcoming in vivo and in vitro studies of their molecular mechanisms in the diagnosis and treatment of pancreatic cancer. The training set consisted of two expression profiles GSE16515 and GSE22780 combined from the Gene Expression Omnibus (GEO) database. A number of helpful hub genes for upcoming

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in vivo and in vitro studies of their molecular mechanisms in the diagnosis and treatment of pancreatic cancer. However, additional biological tests are required to verify molecular pathways in pancreatic cancer cells.

3 Proposed Work Explanation

The initial stage of preprocessing is performed in the input dataset using Wiener filter, which enhances the quality of image and also to remove irrelevant information from the input image. The preprocessed image is separated into many segments during the segmentation phase, using the fuzzy-c-means clustering algorithm. The feature extraction approach is applied to the segmented regions in order to extract many features that facilitate the classification process. The method used for feature extraction is called GRCM, a sophisticated method that is widely applied to extract relevant features for classification. Finally, CNN-GWO is utilized for classification. As a consequence, best results are obtained with the highest level of dependability.

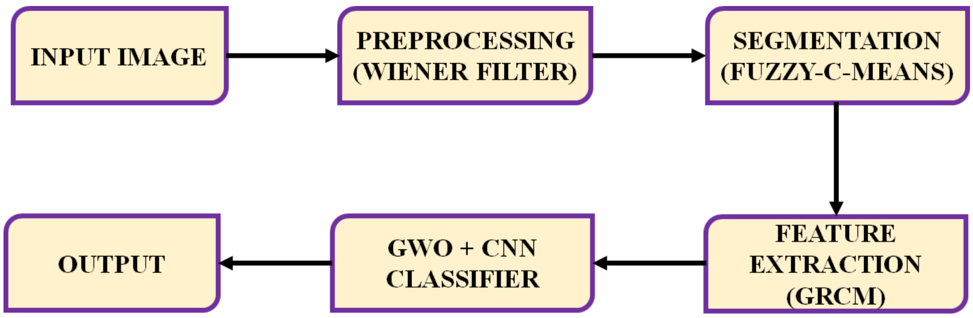

Figure 1: *Proposed Block Diagram*

3.1 Preprocessing

Despite geometric alterations to images, pre-processing seeks to improve the image data by reducing undesired distortions or emphasizing specific visual aspects that are crucial for further processing.

3.1.1 Wiener Filter

The process of removing noise from the original image is called pre-processing, sometimes referred to as picture restoration. Utilizing linear motion or unfocused optics is the most important technique for eliminating blur from images. The Weiner filter is used to strike a compromise between distortion insertion and noise reduction. These filters were used in the pre-processing step of the ASR system. Noise, not distortion, was the reason for the decline in recognition performance in the instance of AWGN. The two primary components of the Wiener filter are the knowledge of the original signal's spectral features and the search for a linear time invariant filter; the outcomes of both would most likely be comparable to the original signal.

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Wiener filtering typically necessitates an understanding of the original image's and the noise's power spectra beforehand. The Wiener filter R (u)'s simplified equation is provided below.

$$R(u) = \frac{H(u)^*}{|H(u)|^2 + K} \quad (1)$$

Where H (u) is the signal's Fourier transform and R (u) is the output.
Wiener filter's primary characteristic is that it allows the time-dependent noise factor to vary from frame to frame and makes it inversely dependent on SNR. This will guarantee a stronger suppression of frames containing simply noise and a weaker suppression of the chirp signal during its segmentation procedure. As a result, the noisy areas in the input image are eliminated using this filter.

3.2 Segmentation

In digital image processing and analysis, image segmentation is a widely used technique that divides a picture into various portions or areas, usually depending on the properties of the image's pixels. Image segmentation is breaking down a picture into a group of pixel-rich areas that can be represented by a labeled image or a mask. Over time, numerous alternative methods for segmenting images have been created, utilizing domain-specific expertise to efficiently address segmentation issues in certain application domains. So let's begin with fuzzy C-Means segmentation, one of the clustering-based methods used in image segmentation.

3.2.1 Fuzzy C Means

Partitioning a picture into different subgroups (pixels) known as picture Objects is a procedure known as segmentation. The image's complexity is decreased in this system through segmentation using the Fuzzy-C-Means technique. By decreasing the weighted within group sum of squared error objective function, the algorithm an iterative clustering technique produces an ideal c partitionJ_{FCM}.

$$J_{FCM} = \sum_{k=1}^{n} \sum_{i=1}^{c} (u_{ik})^q \, d^2(x_k, v_i) \quad (2)$$

Where, X = {x1, x2, · · ·, xn} ⊆ R p is the data set in the p-dimensional vector space.
Where n denotes number of data items, c is the number of clusters with $2 \leq c < n$, u_{ik} is the degree of membership of x_k in i^{th} cluster, q is a weighting exponent on each fuzzy membership, v_i is the prototype of Centre of cluster i and $d^2(x_k, v_i)$ specifies the distance measure between object x_k and cluster Centre v_i.

3.3 Feature Extraction

A technique for extracting an image's visual content for indexing and retrieval is called feature extraction. Either domain-specific characteristics or universal features, such the extraction of colour, texture, and shape, can be found in primitive or low-level picture features.

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3.3.1 Gabor Based Region Covariance Matrix

The GRCM technique is used to process the segmented areas and extract features, it plays a very important role in the feature extraction process since it helps identify lesions as accurately as possible. Pixel position and Gabor coefficient contribute to the formation of the covariance matrix. Colour, texture, and shape are used to describe the area. One crucial component in identifying and categorizing objects is their texture. Texture is described by contrast, homogeneity, dissimilarity, energy, and entropy. Texture images are used to measure changes in intensity.

3.4 Classification

The idea of classification functions as a means of displaying components, classes, data types, and interfaces. A classifier is a set of cases with shared structural and behavioural characteristics. In this study, the effective (GWO based CNN) classification is applied.

3.4.1 Convolutional Neural Network

An artificial neural network that is specifically made to interpret pixel input is called a CNN, and it is utilized in image recognition and processing. An image's items can be identified using this approach. Images are made out of RGB combo data. 3D arrays are used to store colour images. The image's height and breadth (or pixel count) are represented by the first two dimensions. The red, green, and blue hues found in every pixel are represented by the final dimension. An enhanced CNN technique is needed to get better categorization.

3.5 Grey Wolf Optimization (GWO)

The GWO algorithm mimics the hunting strategy and leadership structure of natural grey wolves. Alpha, beta, delta, and omega are the four different kinds of grey wolves that are used to simulate the leadership hierarchy. There are four distinct hunting strides that characterize grey wolves. It is straightforward, adaptable, scalable, and simple to use. The grey wolf method iterates faster than other optimization algorithms because it compares and ranks various options in relation to the ideal solution.

3.6 GWO Based CNN Classifier

Among various meta-heuristic methods, GWO algorithm is well-liked for its quick convergence and precise solution determination. The CNN network's optimal and significant hyper-parameters are calculated using a well-liked swarm intelligence method called GWO. "Classification" errors are decreased by using the GWO approach. Compared to conventional models, the suggested GWO-based CNN model performs better in classification. Therefore, the GWO-based CNN model finds its usefulness in crop stage detection and picture classification applications, particularly in distant applications with constrained computer resources.

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4 Results and Discussion

4.1 Input Image

The pancreas image that needs to be checked is shown in figure 2.

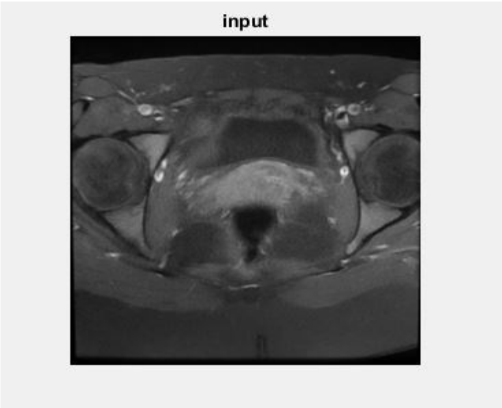

Figure 2: *Input image of pancreas*

4.2 Preprocessing

Pre-processing is the process of eliminating noise from the raw image. Wiener filter is used to eliminate noise from the input image. Figure 3 displays the filtered, or noise-removed, image.

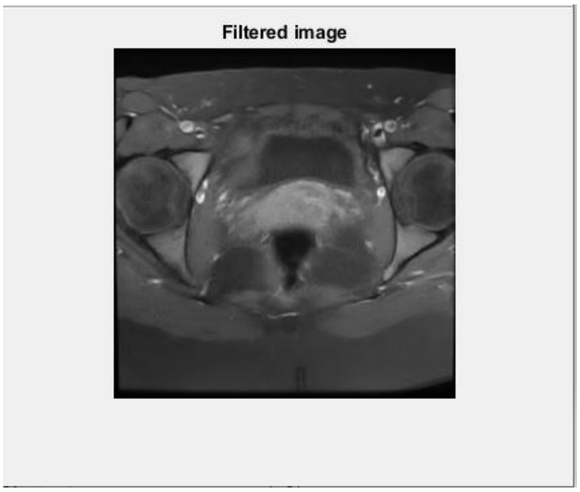

Figure 3: *Filtered image*

Figure 4 shows an example of a histogram analysis. Similar photos to a query image are processed by Histogram Analysis. Past researchers and pathologists who have closely examined pathological specimens have generated numerous significant discoveries about

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diseases like cancers and infectious disorders. Professional pathologists can also profit from it, particularly when uncommon cases are anticipated.

Figure 4: *Hist Analysis*

Figure 5 presents an adaptive image binarization, where the page is seen as a collection of smaller pieces, including text, background, and images. It tackles the problems caused by illumination, noise, and various degradations connected to source types.

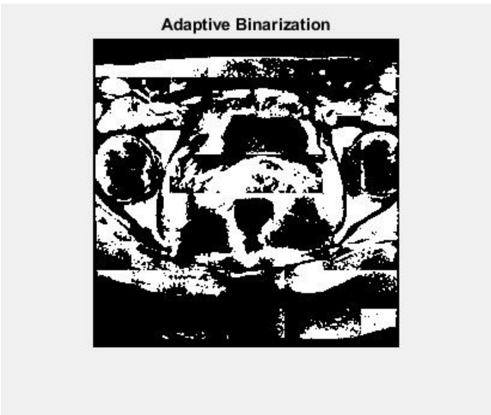

Figure 5: *Adaptive Binarization*

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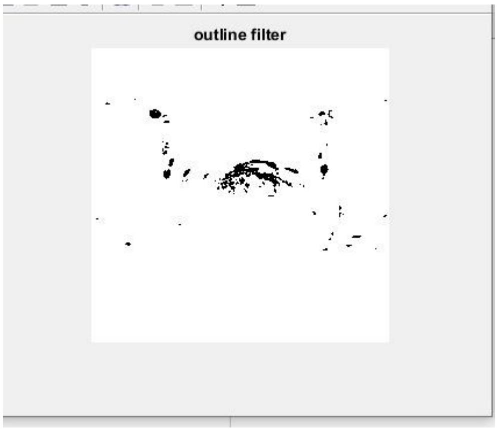

Figure 6: *Outline Filter*

In Figure 6, the outline filter is demonstrated. The purpose of applying filters is to adjust or improve the characteristics of the photographs and/or extract useful data from them, like blobs, corners, and edges.

4.3 Segmented Image

The division of a digital image into several segments is called segmentation. In order to distinguish between tumor and non-neoplastic regions during segmentation, the pixel range must first be standardized by intensity standardization. After that, the segmentation result is obtained and the non-brain regions are masked. Next, as illustrated in figure 7, the filtered image is segmented using the fuzzy-C-Means segmentation technique.

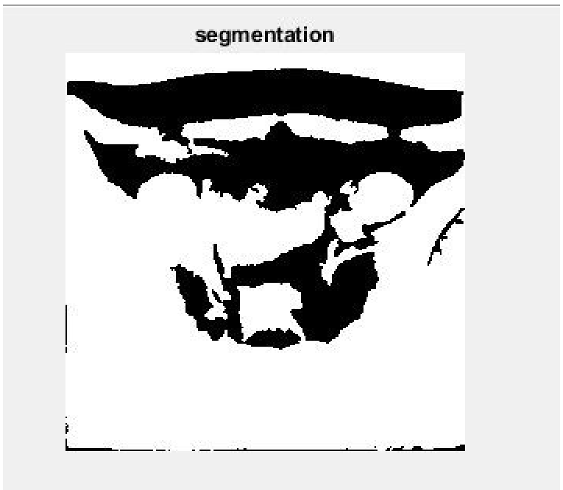

Figure 7: *segmented image*

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4.4 Edge Detection

Edge detection is used in Figure 8 to identify object boundaries in images. In fields including image processing, computer vision, and machine vision, edge detection is utilized for data extraction and image segmentation. It operates by looking for brightness discontinuities.

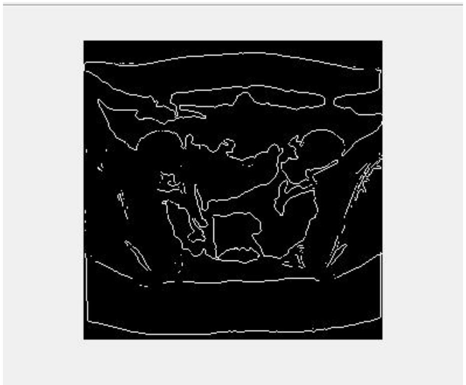

Figure 8: *Edge detection*

4.5 Output Image

The Montage of Gabor Magnitude Output Images is shown in Figure 9. In essence, the Gabor filter is a linear filter used for texture analysis that determines whether a picture contains any particular frequency content in certain directions within a confined region surrounding the point or region of investigation.

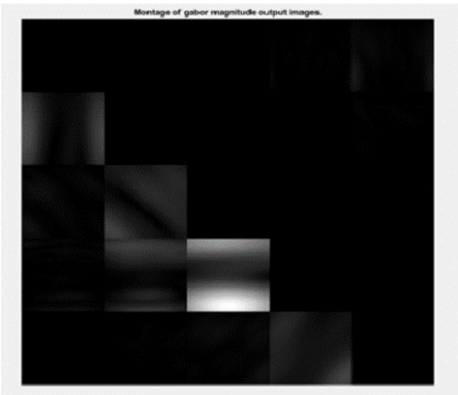

Figure 9: *Montage of Gabor Magnitude Output Images*

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4.6 Gabor Magnitude and Gabor Phase

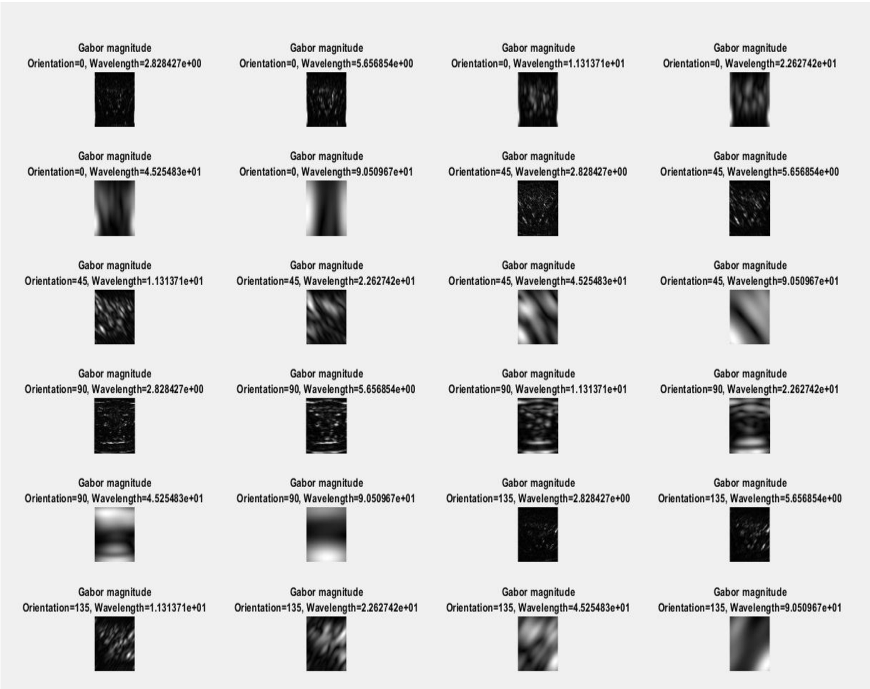

Figure 10: *Gabor Magnitude*

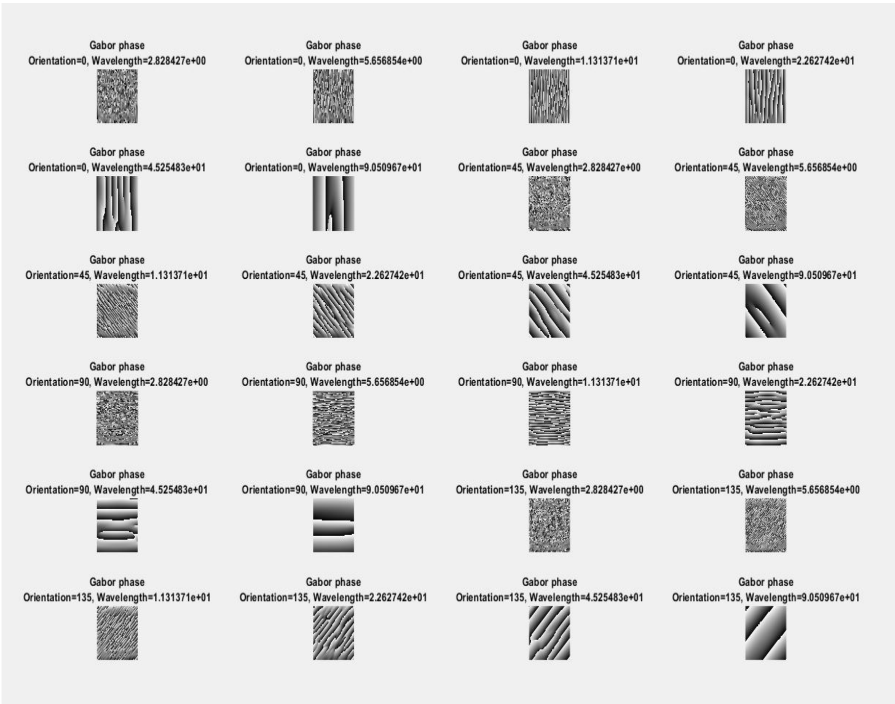

Figure 11: *Gabor Phase*

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Two Gabor features that are resistant to changes in light are Gabor phase and Gabor magnitude. In particular, the Gabor magnitude feature is known to be resilient to changes in illumination, and the large-step quantizing procedure used in the proposed quantized Gabor phase codes likewise produces robustness. The performances of Gabor phase and Gabor magnitude are displayed in Figures 10 and 11, respectively.

4.7 GWO Optimization

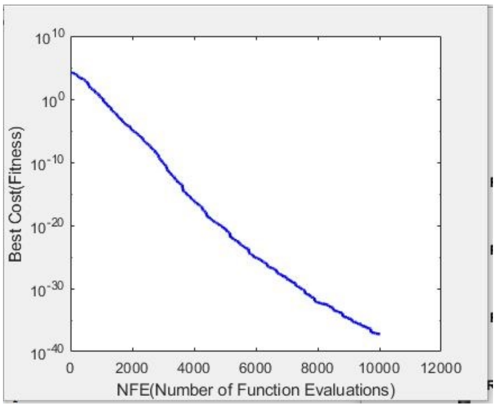

Figure 12: *GWO Optimization*

Figure 12 shows the optimization of GWO. Image processing difficulties are among the many time-consuming challenges for which the gray wolf optimization technique is employed. This graph illustrates the relationship between the number of functions and the best cost. The operational cost of the overall complex problem is typically decreased by using the gray wolf optimization technique.

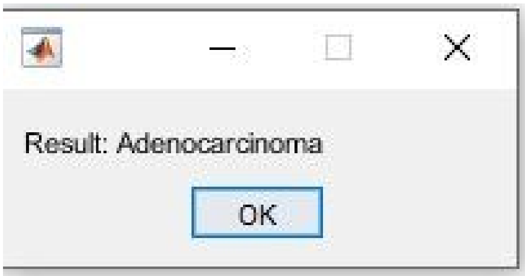

Figure 13: *Output Image*

The sort of pancreatic cancer that is discovered is seen in figure 13 above. A clear classification of cancer kinds, including pancreatic cancer, is provided by the suggested method. This approach is helpful not just for categorization but also for early cancer diagnosis, which is critical for prompt treatment.

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5 Conclusion

This research develops a convolutional neural network classifier for the diagnosis of pancreatic cancer. Pre-processing is the approach used to obtain high-quality photographs. Wiener filter is used in the pre-processing method. The preprocessed image is separated into many segments using the fuzzy-c-means clustering approach, which then segments the processed image. To facilitate classification, many features are extracted from the segmented regions using a feature extraction technique. The feature extraction for the advanced approach makes use of the GRCM (Gabor based Region Covariance Matrix) technology. Convolutional neural networks are finally used for categorization. The CNN Classifier is tailored to provide an accurate diagnosis of pancreatic cancer. In contrast to other classifiers, the CNN classifier has superior performance. In this project, MATLAB simulation software is used.

Reference

1. Min Li; Xiaohan Nie; Yilidan Reheman; Pan Huang; Shuailei Zhang; Yushuai Yuan; Chen Chen; Ziwei Yan; Cheng Chen; Xiaoyi Lv; Wei Han, Year: 2020, “Computer-aided diagnosis and staging of pancreatic cancer based on CT images”, IEEE Access, Vol: 8, pp. 141705 – 141718.

2. Deepesh Agarwal; Obdulia Covarrubias-Zambrano; Stefan H. Bossmann; Balasubramaniam Natarajan, Year: 2022, “Early detection of pancreatic cancers using liquid biopsies and hierarchical decision structure”, IEEE Journal of Translational Engineering in Health and Medicine, Vol: 10, pp. 1 – 8.

3. Yucheng Li; Yang Liu; Kashu Yamazaki; Mingfeng Bai; Yue Chen, Year: 2021, “Development of a soft robot based photodynamic therapy for pancreatic cancer”, IEEE/ASME Transactions on Mechatronics, Vol: 26, no: 6, pp. 2977 – 2985.

4. Alissa Hendricks-Wenger; Jacqueline Sereno; Jessica Gannon; Allison Zeher; Rebecca M. Brock; Natalie Beitel-White; Alexander Simon; Rafael V. Davalos; Sheryl Coutermarsh-Ott; Eli Vlaisavljevich; Irving Coy Allen, Year: 2021, “Histotripsy ablation alters the tumor microenvironment and promotes immune system activation in a subcutaneous model of pancreatic cancer”, IEEE transactions on ultrasonics, ferroelectrics, and frequency control, Vol: 68, no: 9, pp. 2987 – 3000.

5. Lucia Sarcina; Fabrizio Viola; Francesco Modena; Paolo Bollella; Mario Caironi; Irene Esposito; Luisa Torsi; Fabrizio Torricelli; Eleonora Macchia, Year: 2022, “Large-area bio-electronic sensors for early detection of pancreatic-biliary cancer protein markers”, In 2022 IEEE International Conference on Flexible and Printable Sensors and Systems (FLEPS) (pp. 1 – 4). IEEE.

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6. Himali Ghorpade; Jayant Jagtap; Shruti Patil; Ketan Kotecha; Ajith Abraham; Natally Horvat; Jayasree Chakraborty, Year: 2023, “Automatic Segmentation of Pancreas and Pancreatic Tumor: A Review of a Decade of Research”, IEEE Access.

7. Ajanthaa Lakkshmanan; C. Anbu Ananth; S. Tiroumalmouroughane, Year: 2022, “Multi-objective Metaheuristics with Intelligent Deep Learning Model for Pancreatic Tumor Diagnosis”, Journal of Intelligent & Fuzzy Systems, Vol: 43, no: 5, pp. 6793 – 6804.

8. Min Li; Xiaohan Nie; Yilidan Reheman; Pan Huang; Shuailei Zhang; Yushuai Yuan; Chen Chen; Ziwei Yan; Cheng Chen; Xiaoyi Lv; Wei Han, Year: 2020, “Computer-aided diagnosis and staging of pancreatic cancer based on CT images”, IEEE Access, Vol: 8, pp. 141705 – 141718.

9. Xiahan Chen; Xiaozhu Lin; Qing Shen; Xiaohua Qian, Year: 2020, “Combined spiral transformation and model-driven multi-modal deep learning scheme for automatic prediction of TP53 mutation in pancreatic cancer”, IEEE Transactions on Medical Imaging, Vol: 40, no: 2, pp. 735 – 747.

10. Kaushik Sekaran; Chandana Pethakamsetty; N. Murali Krishna; Seifedine Kadry, Year: 2020, “Deep learning convolutional neural network (CNN) With Gaussian mixture model for predicting pancreatic cancer”, Multimedia Tools and Applications, Vol: 79, no: 15-16, pp. 10233 – 10247.

11. Deepesh Agarwal; Obdulia Covarrubias-Zambrano; Stefan H. Bossmann; Balasubramaniam Natarajan, Year: 2022, “Early Detection of Pancreatic Cancers Using Liquid Biopsies and Hierarchical Decision Structure”, in IEEE Journal of Translational Engineering in Health and Medicine, Vol: 10, pp. 1 – 8.

12. Yucheng Li; Yang Liu; Kashu Yamazaki; Mingfeng Bai; Yue Chen, Year: 2021, “Development of a Soft Robot Based Photodynamic Therapy for Pancreatic Cancer”, in IEEE/ASME Transactions on Mechatronics, Vol: 26, no: 6, pp. 2977 – 2985.

13. Yan Wang; Peng Tang; Yuyin Zhou; Wei Shen; Elliot K. Fishman; Alan L. Yuille, Year: 2021, “Learning Inductive Attention Guidance for Partially Supervised Pancreatic Ductal Adenocarcinoma Prediction”, in IEEE Transactions on Medical Imaging, Vol: 40, no: 10, pp. 2723 – 2735.

14. Zhitong Chen; Li Lin; Eda Gjika; Xiaoqian Cheng; Jerome Canady; Michael Keidar, Year: 2018, “Selective Treatment of Pancreatic Cancer Cells by Plasma-Activated Saline Solutions”, in IEEE Transactions on Radiation and Plasma Medical Sciences, Vol: 2, no: 2, pp. 116 – 120.

15. Chunyang Li; Xiaoxi Zeng; Haopeng Yu; Yonghong Gu; Wei Zhang, Year: 2018, “Identification of hub genes with diagnostic values in pancreatic cancer by bioinformatics analyses and supervised learning methods”, World Journal of Surgical Oncology, Vol: 16, no: 1, pp. 1 – 12.