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Original Article

# A Fuzzy Logic–Based Intelligent System for Early Risk Identification of Pancreatic Ductal Adenocarcinoma

**Rewati Rane[1], Dr. Dnyaneshwari Patil[2]**
[1]Dr. G. Y. Pathrikar college of Computer Science and Information Technology Ch. Sambhajinagar Maharashtra
[2]MITADT University Loni Kalbhor Pune

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***Correspondence Address:***
*Rewati Rane*
*Dr. G. Y. Pathrikar college of Computer Science and Information Technology Ch.Sambhajinagar Maharashtra*
*Email: 1r4rewa@gmail.com*

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***Abstract***

*Pancreatic ductal adenocarcinoma (PDAC) is one of the most aggressive malignancies, often diagnosed at an advanced stage due to the absence of early clinical symptoms. Early identification and risk stratification are therefore crucial to improving patient outcomes and survival rates. This study presents an intelligent decision-support system based on fuzzy logic for the early identification and categorization of PDAC risk using patient clinical data. Key input parameters such as age at diagnosis, tumor classification, treatment type, and vital status are incorporated into a Fuzzy Inference System (FIS). The proposed model classifies patients into Low, Medium, and High-Risk groups using a transparent rule-based reasoning mechanism. The Mamdani-type fuzzy logic approach enables effective handling of uncertainty and imprecision inherent in medical data, while maintaining interpretability for clinical decision-making. Experimental evaluation demonstrates that the proposed system can effectively support early risk assessment and assist clinicians in diagnosis and treatment planning. The results highlight the potential of fuzzy logic–based models as reliable and interpretable tools for early PDAC risk prediction.*

***Keywords*** *Pancreatic Ductal Adenocarcinoma; Fuzzy Logic System; Medical Decision Support System; Early Cancer Diagnosis; Risk Classification; Machine Learning; Fuzzy Inference System*

## Introduction

Pancreatic ductal adenocarcinoma (PDAC) is a highly poisonous tumor of the digestive system with few symptoms until the cancer is advanced. It ranks as the seventh leading cause of cancer death in both male and female combined.

The pancreas is a spongy organ that has been located at the back of the stomach, in the top left portion deep within the abdomen. It is approximately 6 inches long. Pancreas is a vital organ which plays an essential role in converting the food we have into liquid for the proper functioning of our body cells. Functional importance of pancreas such as endocrine and exocrine makes it vital organ of body. Sugar level of the blood is maintained by endocrine while digestion system support is played by exocrine. Food conversion in liquid format for proper functioning of body cells is carried out by Pancreas. Pancreatic adenocarcinoma, known as pancreatic ductal adenocarcinoma, is exocrine tumors which occurs in the tissues of exocrine covers 95% of pancreatic cancer. Apart from adenocarcinoma other exocrine tumors are mucinous cystadenocarcinoma, adenosquamous carcinoma and acinar cell carcinoma. Another type is endocrine tumors which occurs 10%. Commonly used diagnostic tools are Magnetic resonance imaging (MRI) and computed tomography (CT). Analysis of location of tumor & ratio of its spread is majorly done with help of CT scan. Severity of this disease is more as its symptoms are observed when its spread in other body parts impacting functioning.

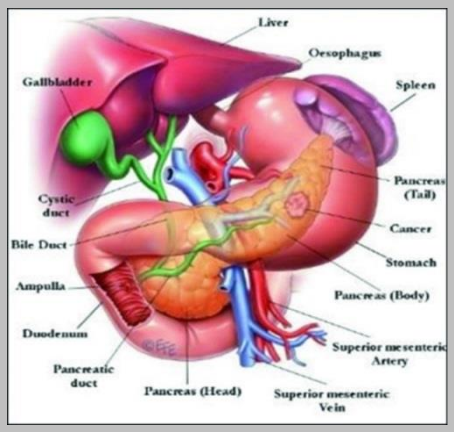


**Fig. 1:** Structure of pancreas

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*This is an open access journal, and articles are distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International Public License, which allows others to remix, tweak, and build upon the work noncommercially, as long as appropriate credit is given and the new creations ae licensed under the idential terms.*

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The structure of pancreas is shown in figure. [8]

**Literature Review**

The focus of the study is to develop a system using machine learning algorithms for early diagnosis of the ductal adenocarcinoma pancreatic disease from the patient's data. Using this literature review we study several machine learning techniques including data pre-processing, feature selection, classification to determine early diagnosis and prediction of pancreatic disease using ML techniques are shown in the following table.

**Table 1: Literature review of the study**

| Sr. No | Author | Title & Year | Journal | Methodology |
|---|---|---|---|---|
| 1 | H. S. Saraswathi, Mohamed Rafi, K. G. Manjunath, and Channa Krishna Raju | Computer-Aided Diagnosis of Pancreatic Ductal Adenocarcinoma Using Machine Learning Techniques (Oct 2021) | Advances in Intelligent Systems and Computing | The paper proposes a computer-aided diagnostic framework for early detection of PDAC using machine learning and biomarker analysis. It focuses on identifying high-risk individuals and analysing urine-based non-invasive biomarkers such as LYVE1, REG1A, REG1B, TFF1, miRNAs, and CA19-9. The collected clinical and biomarker data are pre-processed, relevant features are extracted and selected, and classification models such as logistic regression, SVM, and neural networks are applied to compute a risk score. Model performance is evaluated using sensitivity, specificity, and ROC analysis to assess early-stage PDAC detection accuracy. |
| 2 | Hao Fu, Weiming Mi, Boju Pan , Yucheng Guo , Junjie Li, Rongyan Xu, Jie Zheng, Chunli Zou, Tao Zhang , Zhiyong Liang, Junzhong Zou and Hao Zou | Automatic Pancreas Segmentation Using Coarse scaled 2D Model of Deep Learning: Usefulness of Data Augmen-tation & Deep U-Net (June2021) | Frontiers in Oncology | The proposed methodology employs a Mamdani-type fuzzy logic system for early risk identification of pancreatic ductal adenocarcinoma using clinical patient data. Key input parameters such as age at diagnosis, tumor classification, treatment type, and vital status are fuzzified into linguistic variables. A rule-based inference mechanism evaluates these inputs to determine the PDAC risk level. Finally, defuzzification is applied to classify patients into Low-, Medium-, or High-Risk categories, enabling interpretable and effective clinical decision support. |
| 3 | Yingda Xia1, Qihang Yu1, Wei Shen1(B), Yuyin Zhou1, Elliot K. Fishman2, and Alan L. Yuille1 | Detecting Pancreatic Ductal Adenocarcinoma in Multi-phase CT scans via Alignment Ensemble (October 2020) | Springer | The paper presents a deep learning–based framework for detecting PDAC from multi-phase CT scans (arterial and venous) using cross-phase alignment strategies. Three alignment approaches are explored: early alignment (image-level registration), late alignment (high-level feature-space alignment), and slow alignment (multi-level progressive feature alignment). Each aligned representation is processed through a U-Net–based segmentation network to identify pancreas structures and PDAC lesions. Finally, an alignment ensemble combines predictions from all three strategies, significantly improving detection and segmentation performance. |
| 4 | Jimmy Singla, Balwinder Kaur, Deepak Prashar, Sudan Jha, Gyanendra Prasad Joshi, Kyungyun Park, Usman Tariq, and Changho Seo | A Novel Fuzzy Logic-Based Medical Expert System for Diagnosis of Chronic Kidney Disease (June 2020) | https://doi.org/10.1155/2020/8887627 | The paper develops a fuzzy logic–based medical expert system to diagnose and classify the stage of Chronic Kidney Disease (CKD). Clinical inputs (nephron functionality, blood sugar, blood pressures, age, BMI, and smoking) are fuzzified using trapezoidal/triangular membership functions derived from clinical guidelines and statistical confidence intervals. A Mamdani fuzzy inference system with expert-defined IF–THEN rules maps these inputs to CKD severity levels, and centroid defuzzification produces a crisp diagnostic output. The system is validated against expert diagnoses on patient cases and implemented in MATLAB, achieving high diagnostic accuracy. |

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| **5** | Yucheng Zhang, Edrise M Lobo-Mueller, Paul Karanicolas, Steven Gallinger, Masoom A Haider, Farzad Khalva | CNN-based survival model for pancreatic ductal adenocarcinoma in medical imaging (February 2020) | BMC Med Imaging Article number: 11 (2020) | The study proposes a CNN-based survival prediction model for pancreatic ductal adenocarcinoma (PDAC) using preoperative CT images. Tumor regions were manually segmented and used as input to a deep convolutional neural network trained with a modified discrete-time survival loss function. Transfer learning was applied by pre training the network on a large lung cancer dataset and fine-tuning it on PDAC cohorts to address limited sample size. The model's performance was evaluated using concordance index and index of prediction accuracy and compared against traditional radiomics and Cox proportional hazards models, demonstrating superior prognostic capability. |
| **6** | R. Balakrishna and R. Anandan | Feature Classification and Analysis of Acute and Chronic Pancreatitis Using Supervised Machine Learning Algorithm (January 2020) | Intelligent Computing in Engineering (pp.241-249) | The paper proposes a supervised machine learning framework for classifying acute and chronic pancreatitis using CT scan images. The methodology begins with image preprocessing using Wiener filtering and histogram equalization to remove noise and enhance contrast. Tumor regions are segmented using an Enhanced Region-Based Active Contour (ERBAC) method, followed by texture feature extraction using the Gray-Level Co-occurrence Matrix (GLCM). Finally, the extracted features are classified using the K-Nearest Neighbor (KNN) algorithm (and compared with SVM), achieving high accuracy in early-stage disease diagnosis. |
| **7** | Himansu Das, Bighnaraj Naik, H.S. Behera | Medical disease analysis using Neuro-Fuzzy with Feature Extraction Model for classification (2020) | Informatics in Medicine Unlocked, Volume 18, | The paper proposes a Linguistic Neuro-Fuzzy with Feature Extraction (LNF-FE) model for medical disease classification. Numerical medical data are first fuzzified into linguistic values (low, medium, high) to handle uncertainty, which increases feature dimensionality. Feature extraction techniques (mainly PCA) are then applied to remove insignificant fuzzified features and reduce complexity. The reduced feature set is finally classified using an ANN with backpropagation. The approach improves accuracy and efficiency across multiple medical datasets |
| **8** | Goli Arji, Hossein Ahmadi, Mehrbakhsh Nilashi, Tarik A. Rashid, Omed Hassan Ahmed,Nahla Aljojo, and Azida Zainol | Fuzzy logic approach for infectious disease diagnosis: A methodical evaluation, literature, and classification (October-December 2019) | Biocybernetics and Biomedical Engineering Volume 39 | The paper follows a Systematic Literature Review (SLR) methodology based on the PRISMA framework to analyze the application of fuzzy logic in infectious disease diagnosis. Relevant studies published between 2005 and 2019 were retrieved from major databases including PubMed, Scopus, Web of Science, and Science Direct using predefined search strings. After applying inclusion and exclusion criteria, selected papers were systematically reviewed and categorized according to disease type, fuzzy logic techniques used, and evaluation metrics. The extracted data were analyzed using descriptive statistics, tables, and visualizations to identify research trends and dominant methodologies. |
| **9** | Adebayo Omotosho, Asani Emmanuel Oluwatobi, Ogundokun Roseline Oluwaseun, Ananti Emmanuel Chukwuka and | A Neuro-Fuzzy Based System for the Classification of Cells as Cancerous or Non-Cancerous (May 2018) | International Journal of Medical research & Health sciences,2018 ISSN No: 2319-5886 | The paper proposes a hybrid neuro-fuzzy diagnostic system for classifying cells as cancerous or non-cancerous using lung CT images. The images are first preprocessed using a median filter for noise removal, segmented using a marker-controlled watershed algorithm, and relevant texture features are extracted using the gray-level co-occurrence matrix (GLCM). These features are then classified by an artificial neural network trained with the back-propagation algorithm. Finally, the outputs |

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| | Adegun Adekanmi | | | corresponding to cancerous cells are fed into a fuzzy inference system to determine the cancer stage, enabling interpretable and accurate medical decision support. |
| **10** | A.Sakthivel , Dr.A.Nagarajan | Cancer detection methodology using fuzzy based classification techniques (March 2018) | International journal of engineering sciences & research technology | The paper proposes a fuzzy-based cancer detection framework that focuses on improving classification accuracy through effective feature selection. Medical cancer data are first preprocessed and split into training and testing sets, after which Rough Set theory combined with a Genetic Algorithm is used to reduce redundant and irrelevant features. The selected optimal feature subset is then classified using Adaptive Neuro-Fuzzy Inference System (ANFIS) and Support Vector Machine (SVM) classifiers. Performance is evaluated using classification accuracy on the Wisconsin Breast Cancer Dataset**,** showing higher accuracy with ANFIS compared to SVM. |

The comparative analysis of this study is the most suitable machine learning algorithms for ductal adenocarcinoma pancreatic disease prediction are ANN, BN, ANFIS, K-NN, SVM, Decision Tree.

**Objectives of the Study**

1. To develop a fuzzy based system to detect cancerous and non-cancerous lung cells.
2. To evaluate the model performance by training and testing on different datasets to determine its optimum performance.
3. To achieve high performance in both classifying and pre detecting the stage of the cancer.
4. To design the user-friendly application to make it useable for general people

**Conclusion**

In the Literature review, I had gone through different machine learning and deep learning techniques for the prediction of disease. The main purpose of this review is to highlight all the previous studies of machine learning algorithms that are being used for detection of ductal adenocarcinoma pancreatic disease. After that, the review of major machine learning techniques ANN, BN, ANFIS, K-NN, SVM, Decision Tree has been provided the techniques deeply elaborate algorithms that are being used for the predictions of pancreatic disease.

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**Conflicts of interest**

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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