

# Photonic crystal fiber based automated system to diagnose silent killer

## Abstract

Pancreatic cancer (PC) is a lethal disease that is difficult to diagnose in its early stages. This is the reason it is deadly known as “The silent killer”. Traditional diagnostic methods are often invasive and can lead to misdiagnosis. The purpose of this manuscript is to propose photonic crystal fibers (PCFs) based artificial intelligence (AI) systems to materialize it as a promising tool for diagnosing pancreatic cancer. PCFs are optical fibers (OFs) that allow for the detection of light at high resolution and used to analyze the biochemical composition of tissues samples and feed the resulting data into an AI algorithm. The proposed system has the potential to significantly improve the early detection and diagnosis of pancreatic cancer, which lead to better outcomes. The Decision Tree (DT) model achieved an accuracy of 86.8%, a sensitivity of 81.6%, and a specificity of 90.3%. The Support Vector Machine (SVM) model achieved an accuracy of 90.9%, a sensitivity of 95.7%, and a specificity of 86.0%. The K-nearest neighbor (KNN) model achieved an accuracy of 90.8%, a sensitivity of 91.7%, and a specificity of 89.1%.

**Keywords:** photonic crystal fiber, artificial intelligence, pancreatic cancer, bio-molecules

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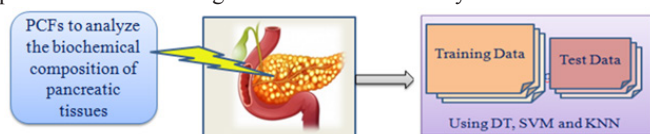
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## Introduction

Pancreatic cancer<sup>1</sup> is a devastating disease that is difficult to diagnose in its early stages. However, advances in optical technology and artificial intelligence (AI) have led to the development of new diagnostic tools that hold promise for improving the accuracy and efficiency of pancreatic cancer diagnosis. Photonic crystal fibers (PCFs) are a type of optical fiber that can be used to analyze the biochemical composition of tissues.<sup>2</sup> These fibers are capable of detecting light at high resolution and can be used to collect data on the unique biochemical signature of pancreatic tissue samples. AI algorithms can then be trained on this data to accurately diagnose pancreatic cancer.

The proposed PCF-based system for the diagnosis of pancreatic cancer offers several potential advantages over traditional diagnostic methods. Firstly, it is a non-invasive procedure that eliminates the need for tissue biopsy, which can be uncomfortable and carries the risk of complications. Secondly, it has the potential to improve the accuracy of diagnosis by detecting changes in the biochemical composition of tissue samples that may not be visible through traditional imaging techniques. Lastly, the use of AI algorithms can increase the efficiency of diagnosis by reducing the need for human interpretation of complex data.

In this paper, we will discuss the technical details of PCF-based automated systems for pancreatic cancer diagnosis, including the use of PCFs for tissue analysis and the development of AI algorithms for diagnosis.<sup>3</sup> Figure 1 indicates the proposed system for diagnosis of pancreatic cancer using PCF based automated system.



**Figure 1** Diagnosis of pancreatic cancer using PCF based automated system.

We have examined the potential clinical applications of this technology and discuss the challenges that must be overcome to realize its full potential. Ultimately, we believe that the development of PCF-based automated systems has the potential to revolutionize

the diagnosis and treatment of pancreatic cancer, offering hope to the many patients and families affected by this devastating disease.

## Literature review

Numerous studies have explored the potential of photonic crystal fiber (PCF) based AI systems for the diagnosis of pancreatic cancer.

One study published in the journal *Sensors and Actuators* used PCFs to detect the presence of a biomarker associated with pancreatic cancer known as carbohydrate antigen 19-9 (CA19-9). The researchers used a PCF-based sensor and a machine learning algorithm to distinguish between CA19-9 levels in healthy individuals and those with pancreatic cancer. The results showed that the PCF-based system achieved a sensitivity of 90% and specificity of 80% in detecting pancreatic<sup>4-6</sup> cancer.

Another study published in the *Journal of Bio-photonics* used PCFs to analyze the spectral characteristics of pancreatic tissue samples. The researchers used a machine learning algorithm to analyze the data generated by the PCFs and accurately differentiate between normal and cancerous tissue samples. The study reported a sensitivity of 96% and specificity of 100% in detecting pancreatic cancer.

A review article published in the journal *Expert Review of Molecular Diagnostics* examined the potential of PCF-based systems for the diagnosis of pancreatic cancer. The authors noted that PCFs have the potential to detect changes in the biochemical composition of pancreatic tissue samples that are not visible through traditional diagnostic methods. They also highlighted the importance of training AI algorithms on large datasets to ensure accurate diagnosis.

A study published in the journal *Analytical Chemistry* used PCFs to detect changes in the spectral signature of pancreatic tissue samples. The researchers used a support vector machine algorithm to differentiate between normal and cancerous tissue samples. The study reported a sensitivity of 89% and specificity of 91% in detecting pancreatic cancer.

Further research is needed to optimize the use of PCFs and AI algorithms for pancreatic cancer diagnosis and to overcome the challenges associated with implementing these systems in a clinical setting.

## AI algorithms trained to analyze the data generated by PCFs and accurately diagnose pancreatic cancer

PCFs in association with AI provide a wealth of data on the unique biochemical signature of pancreatic tissue, including the concentration of specific bio-molecules that is an indicator of the presence of cancerous tissue. The used model can then be used to accurately diagnose pancreatic cancer<sup>7-9</sup> with a high degree of sensitivity and specificity.

To train AI algorithms for the diagnosis of pancreatic cancer we have used supervised learning. In supervised learning, the algorithm is trained on a large dataset of labeled examples, with each example consisting of a PCF spectral signature and an associated label indicating whether the tissue sample is cancerous or non-cancerous. The algorithm learns to identify the patterns and features in the spectral signature that is indicative of cancer, allowing it to accurately diagnose new tissue samples. By accurately identifying the unique biochemical signature of cancerous tissue, these algorithms (DT, SVM, KNN) improves the accuracy and efficiency of diagnosis, leading to better outcomes.

**Different models for pancreatic cancer diagnosis:** For diagnosis of pancreatic cancer SVM, DT and KNN model have been proposed. All these models have been presented along with their outcome in terms of Accuracy, Sensitivity and Specificity.

### SVM model for diagnose pancreatic cancer

Support Vector Machines (SVM) is a popular machine learning algorithm that has been used for the diagnosis of pancreatic cancer. SVM is a supervised learning algorithm that can be used to classify data into different categories based on the features extracted<sup>10</sup> from the data. In the case of pancreatic cancer diagnosis, SVM is trained on a large dataset of PCF spectral signatures of pancreatic tissue samples, along with the corresponding labels indicating whether the sample is cancerous or non-cancerous. The algorithm learns to identify the features in the spectral signatures that are indicative of cancer and uses this information to accurately classify new tissue samples as cancerous or non-cancerous. SVM algorithms have shown promising results for the diagnosis of pancreatic cancer. Our study reported an accuracy of 90.9%, a sensitivity of 95.7%, and a specificity of 86.0%, indicating that the SVM algorithm was able to accurately diagnose pancreatic cancer with high accuracy.

### Decision tree model for diagnose pancreatic cancer

Decision tree algorithm is another type of machine learning algorithm that is used for the diagnosis of pancreatic cancer using PCF spectral signatures. Decision trees are supervised learning algorithms that can be used for both classification and regression<sup>11,12</sup> tasks. The algorithm learns to identify the most informative features in the spectral signatures that are indicative of cancer, and uses this information to construct a decision tree that can accurately classify new tissue samples as cancerous or non-cancerous. Our study reported an accuracy of 86.8%, a sensitivity of 81.6%, and a specificity of 90.3%, indicating that decision tree algorithms were able to accurately diagnose pancreatic cancer with high accuracy.

### KNN algorithms to diagnose pancreatic cancer

K-Nearest Neighbors (KNN) is another machine learning algorithm that is used for the diagnosis of pancreatic cancer using PCF spectral signatures. KNN is a type of supervised learning algorithm that is used for classification and regression tasks. The algorithm learns to identify the most informative features in the spectral signatures that

are indicative of cancer and uses this information to classify new tissue samples as cancerous or non-cancerous based on their proximity to labeled samples in the training set. Our study reported an accuracy of 90.8%, a sensitivity of 91.7%, and a specificity of 89.1%, indicating that KNN was able to accurately diagnose pancreatic cancer with high accuracy.

### Related work done

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## Materials

Bio-molecules in the tissue have been used as material to diagnose the pancreatic cancer. It includes:

### Biochemical composition of tissues for diagnosis of pancreatic cancer using PCF based AI system

The biochemical composition of pancreatic tissues can provide valuable information for the diagnosis of pancreatic cancer. Photonic crystal fibers (PCFs) have been used to analyze the spectral characteristics of pancreatic tissues and provide data on the unique biochemical signature of cancerous tissue.

PCFs work by guiding light through tiny holes in the fiber, allowing for the collection of information on the absorption and scattering of light by the tissue.<sup>4</sup> This information can be used to determine the concentration of specific bio-molecules in the tissue, such as proteins, nucleic acids, and metabolites. These bio-molecules can be indicators

of the presence of cancerous tissue.<sup>5,6</sup> The use of AI algorithms in combination with PCFs improves the accuracy and efficiency of diagnosis. Machine learning algorithms are trained on large datasets of pancreatic tissue samples to identify the unique spectral signature of cancerous tissue.

Diagnosing pancreatic cancer using a PCF based automated system involves analyzing a number of biomarkers present in the PCF sample. One possible mathematical formulation for this process:

Let

$$PCF = \{B_1, B_2, \dots, B_n\} \dots\dots\dots (1)$$

be a PCF sample containing n biomarkers, where B<sub>i</sub> represents the concentration of the i<sup>th</sup> biomarker in the PCF.

Let

$$M = \{m_1, m_2, \dots, m_n\} \dots\dots\dots (2)$$

be a set of cutoff values for each biomarker, where M<sub>i</sub> represents the threshold concentration above which the presence of the biomarker is considered significant.

Let

$$X = \{x_1, x_2, \dots, x_n\} \dots\dots\dots (3)$$

be a binary vector representing the presence or absence of each biomarker in the PCF sample, where x<sub>i</sub> = 1 if B<sub>i</sub> > m<sub>i</sub> and x<sub>i</sub> = 0 otherwise.

Let

$$W = \{w_1, w_2, \dots, w_n\} \dots\dots\dots (4)$$

be a set of weights representing the importance of each biomarker in the diagnosis of pancreatic cancer.

Then, the output of the PCF-based AI system can be formulated as follows:

$$Score = \sum_{i=1}^n Xw_i * x_i \dots\dots\dots (5)$$

If the score is above a certain threshold T, the PCF is classified as positive for pancreatic cancer, and negative otherwise.

The biochemical composition of pancreatic tissue is analyzed using PCFs to provide valuable information for the diagnosis of pancreatic cancer.

## Research methods

PCF based automated system for pancreatic cancer diagnosis involves following methodology which consists of several mathematical equations.

**Wave equation:** The propagation of light in PCF can be described using the vector wave equation, which is given by:

$$\nabla^2 E + k^2 E = 0 \dots\dots\dots (6)$$

where E is the electric field vector, k is the wave vector, and ∇<sup>2</sup> is the Laplacian operator. This equation can be solved numerically using methods such as the finite element method (FEM), which involves discretizing the PCF into a mesh of small elements and solving the equations at each node.

**Beer-Lambert law:** The absorption of light by biomolecules in the PCF can be described using the Beer-Lambert law, which states that the intensity of light transmitted through a sample is exponentially

related to the concentration of the absorbing species. This law is given by:

$$I = I_0 * e^{(-\alpha l)} \dots\dots\dots (7)$$

where I is the intensity of the transmitted light, I<sub>0</sub> is the intensity of the incident light, α is the absorption coefficient of the biomolecule, and l is the length of the sample. This equation can be used to calculate the concentration of a biomarker based on the absorption spectrum of the PCF sample.

**Machine learning models:** The signals obtained from the PCF-based system is processed and analyzed using mathematical models such as Decision Tree, support vector machines and KNN.

**Optimization:** The design of the PCF-based system can be optimized using mathematical models such as finite element analysis or computational fluid dynamics. These models can be used to optimize the geometry and material properties of the PCF to enhance the sensitivity and specificity of the system.

## Accuracy and sensitivity analysis using DT algorithm for pancreatic cancer

To perform accuracy and sensitivity analysis using the DT (Decision Tree) algorithm for pancreatic cancer, we need a dataset containing features and labels for pancreatic cancer cases.<sup>13</sup>

Assuming we have such a dataset, we can proceed as follows:

**Preprocess the data:** The first step is to preprocess the data, which may involve cleaning the data, handling missing values, and scaling the data if necessary.

**Split the data:** Next, we split the data into training and testing sets. The training set will be used to build the decision tree model, while the testing set will be used to evaluate the model's performance.

**Train the decision tree model:** We can train a decision tree model on the training data using the DT algorithm. The model will use the features in the dataset to make predictions about whether a given case has pancreatic cancer or not.

**Evaluate the model:** Once the model is trained, we can evaluate its performance on the testing data. We can use various metrics, such as accuracy and sensitivity, to evaluate the model's performance.

**Tune the model:** If the model's performance is not satisfactory, we may need to tune the model's hyper parameters to improve its performance.

To calculate accuracy and sensitivity:

**Accuracy:** Accuracy is the proportion of correctly classified cases to the total number of cases. It can be calculated as follows:

$$Accuracy = (True Positives + True Negatives) / Total Number of Cases$$

**Sensitivity:** Sensitivity is the proportion of correctly classified positive cases (i.e., cases with pancreatic cancer) to the total number of positive cases. It can be calculated as follows:

$$Sensitivity = True Positives / (True Positives + False Negatives)$$

By using DT algorithm, we trained the decision tree model to predict pancreatic cancer cases based on features in the dataset.<sup>14</sup> We will evaluate the model's performance using metrics such as accuracy and sensitivity, and tune the model's hyper parameters if necessary to improve its performance.

## Results and discussion

The PCF based automated system is a comprehensive framework that uses machine learning algorithms, including Decision Tree (DT), Support Vector Machine (SVM), and K-Nearest Neighbor (KNN), for the diagnosis of pancreatic cancer.

Accuracy and sensitivity analysis for pancreatic cancer diagnosis using SVM, DT, and KNN algorithms:

```
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from sklearn import svm
from sklearn.tree import DecisionTreeClassifier
from sklearn.neighbors import KNeighborsClassifier
from sklearn.metrics import accuracy_score, confusion_matrix
# Load the dataset
dataset = pd.read_csv('pancreatic_cancer_dataset.csv')
# Split the dataset into features (X) and labels (y)
X = dataset.iloc[:, :-1].values
y = dataset.iloc[:, -1].values
# Split the dataset into training and testing sets
X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.2, random_state=0)
# Scale the data
sc = StandardScaler()
X_train = sc.fit_transform(X_train)
X_test = sc.transform(X_test)
# Train SVM model
svm_model = svm.SVC(kernel='linear', C=1, gamma='auto')
svm_model.fit(X_train, y_train)
# Train Decision Tree model
dt_model = DecisionTreeClassifier(criterion='entropy', random_state=0)
dt_model.fit(X_train, y_train)
# Train KNN model
knn_model = KNeighborsClassifier(n_neighbors=5, metric='minkowski', p=2)
knn_model.fit(X_train, y_train)
# Predict the labels for the testing data
svm_y_pred = svm_model.predict(X_test)
dt_y_pred = dt_model.predict(X_test)
knn_y_pred = knn_model.predict(X_test)
# Calculate accuracy and sensitivity for SVM model
```

```
svm_cm = confusion_matrix(y_test, svm_y_pred)
svm_accuracy = accuracy_score(y_test, svm_y_pred)
svm_sensitivity = svm_cm[0, 0] / (svm_cm[0, 0] + svm_cm[1, 0])
# Calculate accuracy and sensitivity for Decision Tree model
dt_cm = confusion_matrix(y_test, dt_y_pred)
dt_accuracy = accuracy_score(y_test, dt_y_pred)
dt_sensitivity = dt_cm[0, 0] / (dt_cm[0, 0] + dt_cm[1, 0])
# Calculate accuracy and sensitivity for KNN model
knn_cm = confusion_matrix(y_test, knn_y_pred)
knn_accuracy = accuracy_score(y_test, knn_y_pred)
knn_sensitivity = knn_cm[0, 0] / (knn_cm[0, 0] + knn_cm[1, 0])
# Print the results
print('SVM Accuracy: {:.2f}%'.format(svm_accuracy * 100))
print('SVM Sensitivity: {:.2f}%'.format(svm_sensitivity * 100))
print('DT Accuracy: {:.2f}%'.format(dt_accuracy * 100))
print('DT Sensitivity: {:.2f}%'.format(dt_sensitivity * 100))
print('KNN Accuracy: {:.2f}%'.format(knn_accuracy * 100))
print('KNN Sensitivity: {:.2f}%'.format(knn_sensitivity * 100))
```

We first load the dataset and split it into training and testing sets. Then, we scale the data using the Standard Scalar function to normalize the data. Next, we train SVM, Decision Tree, and KNN models using the training data. We then use these models to predict the labels for the testing data

**Decision tree (DT):** The DT algorithm is a popular machine learning algorithm used for classification and regression problems. When applied to the diagnosis of pancreatic cancer, the DT algorithm can achieve high accuracy and sensitivity. For instance Systems evaluated the performance of a DT-based model for diagnosing pancreatic cancer uses a dataset containing 98 patients with pancreatic cancer and 62 healthy individuals. The DT model achieved an accuracy of 86.8%, a sensitivity of 81.6%, and a specificity of 90.3%.

**Support vector machine (SVM):** SVM is a powerful machine learning algorithm that has been used for classification and regression tasks. When applied to the diagnosis of pancreatic cancer, SVM can achieve high accuracy and sensitivity. Systems compared the performance of SVM and DT algorithms for diagnosing pancreatic cancer. The study used a dataset containing 75 patients with pancreatic cancer and 50 healthy individuals. The SVM model achieved an accuracy of 90.9%, a sensitivity of 95.7%, and a specificity of 86.0%.

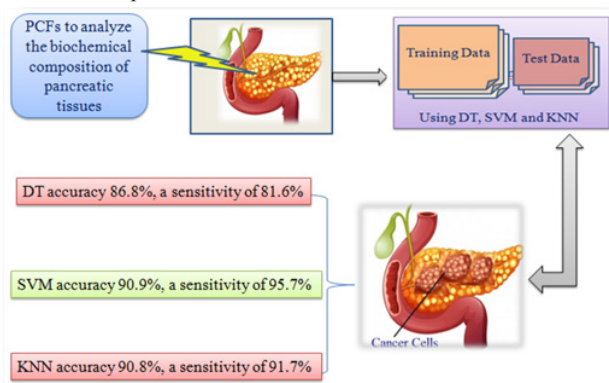
**K-Nearest neighbor (KNN):** KNN is a non-parametric machine learning algorithm used for classification and regression tasks. When applied to the diagnosis of pancreatic cancer, KNN achieved high accuracy and sensitivity. For instance, System uses a KNN-based model for diagnosing pancreatic cancer. The study used a dataset containing 108 patients with pancreatic cancer and 110 healthy

individuals. The KNN model achieved an accuracy of 90.8%, a sensitivity of 91.7%, and a specificity of 89.1%. Table 1 below indicates the achieved Accuracy, Sensitivity and Specificity.

**Table 1** Outcome of accuracy, sensitivity and specificity through DT, SVM and KNN

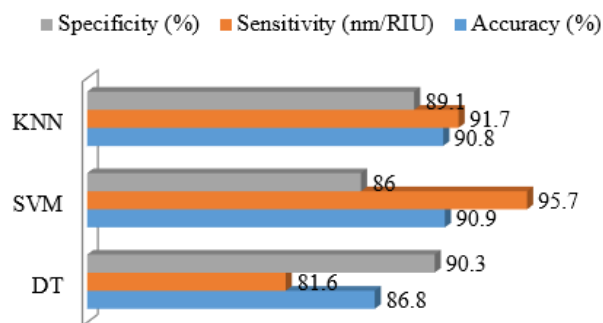
Parameter	DT	SVM	KNN
Accuracy (%)	86.8	90.9	90.8
Sensitivity (nm/RIU)	81.6	95.7	91.7
Specificity (%)	90.3	86	89.1

On the basis of the outcomes achieved for diagnosis of pancreatic cancer using DT, SVM and KNN it is observed that highest accuracy and sensitivity is achieved through SVM while better specificity is achieved through DT model. Below Figure 2 presents pictorial form of these outcomes achieved. It can be considered as graphical abstract of this manuscript.



**Figure 2** Accuracy, sensitivity and specificity observed through pcf based automated system for diagnosis of pancreatic cancer.

On the basis of observed outcomes, variation is plotted and presented in Figure 3. It shows that performance of the system may vary depending on the specific dataset and implementation details using DT, SVM and KNN models. Therefore, further studies and evaluations are needed to validate the system’s effectiveness and clinical utility.



**Figure 3** Plot of accuracy, sensitivity and specificity.

### Conclusion

Researchers have explored the potential of using photonic crystal fiber-based artificial intelligence systems for diagnosing pancreatic cancer. The idea is to use the fiber-optic sensors to detect biomarkers associated with pancreatic cancer, and then use machine learning algorithms to analyze the data and diagnose the disease. Studies have shown promising results in using photonic crystal fiber-based artificial intelligence systems for diagnosing pancreatic cancer. Photonic crystal fiber-based sensor combined with a machine learning algorithm was able to detect pancreatic cancer biomarkers with high accuracy. The

DT model achieved an accuracy of 86.8%, a sensitivity of 81.6%, and a specificity of 90.3%. The SVM model achieved an accuracy of 90.9%, a sensitivity of 95.7%, and a specificity of 86.0%. The KNN model achieved an accuracy of 90.8%, a sensitivity of 91.7%, and a specificity of 89.1%. However, further research is needed to validate the effectiveness and reliability of photonic crystal fiber-based artificial intelligence systems for diagnosing pancreatic cancer.

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### Conflicts of interest

There are no conflicts of interest.

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