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ABSTRACT Tumors caused seveior problem to human beings. Sometime it may be a cause of death. According to WHO 9.1 million deaths have been reported due to tumors. Earlier there were lack of treatment and technological deficiency, due to which it was unable to detect tumor cells and even unable to offer proper treatment for these diseases. The aim of this study is to utilize Photonic crystal (PhC) to undergo in every field of influence that has been utilized them twenty decade back to now a days. Applying photonic crystal sensing techniques and impending applications of PhC for tumor detection of split diseases, unspecified viruses and a range of tumors. Artificial intelligence (AI) is also playing incredibly essential role in analyzing and creating entities equivalent to the change in human behavior. AI tools and techniques have been utilized as a mthod to create intelligent sensing entity through which it has been accomplished. Thanks to Photonics crystal sensors that they have made it true not only for detection but we can say for early detection of such tumors in human body. These early detection and proper investigation is possible only because of AI impacts on photonics crystal. This investigation observed that detection of bio molecules for selectivity, sensitivity, reflectivity and concentration are changes in wavelength i.e. from 1.5 µm to 4 µm the refractive index (RI) of tumor cell can be measured which is observed by measuring sensitivity between 11258 nm/RIU to 32358 nm/RIU. Results shows that support vector machine (SVM) obtained accuracy as 96%, K- nearest neighbor (KNN) shows as 70%, logistic regression (LR) shows as 88%, random forest (RF) show it as 90%, fuzzy logic (FL) and artificial neural network (ANN) observed accuracy as 93% and 95% respectively. It is concluded that refractive indices of Tumors varies between 1.3342 to 1.4251. It is observed that sarcoma level is directly proportional to the RI of tumor.

INDEX TERMS Artificial Intelligence, Bio-sensing, Photonic crystal fiber (PCF), Sensitivity, Sensors.

I. INTRODUCTION

During experimenting on inhibited spontaneous emission [1] in 1987 E. Yablonovitch used the term Photonic crystal. After that several scientists used it in their experiments and designed various photonic crystal structures in one dimension (1D), two dimensions (2D) and three dimensions (3D) [1-2]. Photonic crystal fibers [3] are well known class of Optical fibers [4] and they uses photonic crystals to constitute cladding [5] (outer part of structure) surrounded to core [6] (inner part of structure). M. R. Islam et.al. [7] introduced optical fiber sensing principle and mechanism. He introduced that optical fibers are fundamental need for sensing. In the upcoming future these sensors will be the most widely used sensors in every domain. Due to their properties like immune to EMI (Electromagnetic Interference), inert nature against chemical and biological changes, low transmission loss and high accuracy and fast response [7] optical fiber sensors are mostly used in various sensing applications. Photonic Crystals are low loss periodic arrangements of microscopic air holes which run along the complete length of optical fiber (FIGURE 1). Fiber optic sensors are classified on basis of intensity, spectrally and interferometric based sensors. These sensors offer high surface area in low volume and depict extraordinary sensing properties in biomedical and pharma industries. Various meta materials [8] lead to the advancement of photonics in the designing, modeling and simulating PCF structures. PCF sensors along with dedicated FDTD (finite difference time domain) [9] method among available techniques like finite element method (FEM), scalar effective index method (SEIM), full vectorial method (FVM), full vectorial effective index method (FVEIM) etc uses to analyze and produces outcomes.

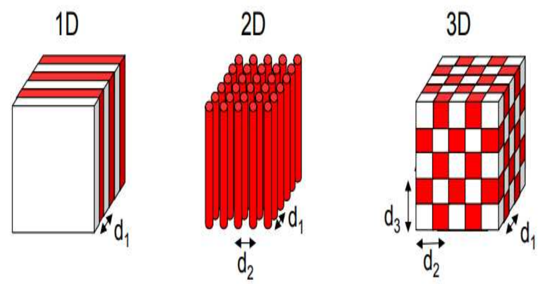


FIGURE 1. Photonic Crystals [1]

The principle of sensing converts whole setup into interfoermetric mode as it superimpose photonic crystal fiber with dedicated photonics crystal material [10] (silica glass Si, borosilicate crown glass Bk7, chalcogenide glass As_2Se_3, borofloat glass, lime soda, etc). In this way PhC performs smart sensing to obtain efficient outcomes. PCF sensors are beneficial over conventional sensors in many aspects as they offer immense design litheness with their holey internal structure (FIGURE 2) [11].

Earlier various investigations have been done for tumor detection but with the implication of AI and photonic crystal sensing it has not been done. This paper is presenting the implications of AI and PhC sensing for tumor detection. The PhC along with the artificial intelligence are utilizing as Optical Neural Network (ONN), Artificial Neural Network (ANN), Cellular Computing, Plasma Technology, Parallel Processing, Image Processing etc. Here in this study designated photonic crystal has been used for the detection of infected cell in human body. The aim of this paper is to offer higher accuracy and sensitivity for detection of tumor with the help of AI technique which will be best suited along with the photonic crystal sensing techniques.

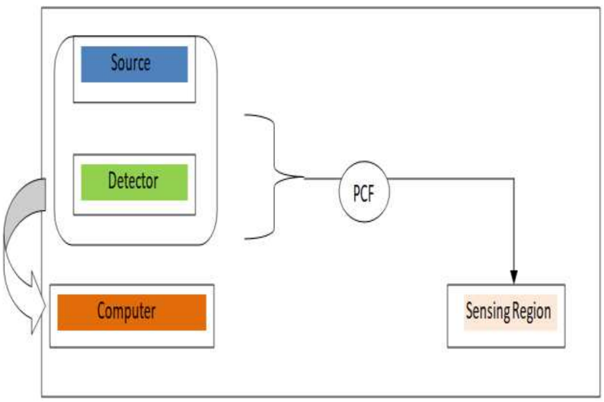


FIGURE 2. PCF sensing and analyzing principle

II. MATERIALS and METHOD

A. DATA SET AND COLLECTION

The Bragg grating is properly designed in order to exhibit a central Bragg center wavelength depending on optical and geometrical properties of the periodic multilayer. Various dataset is collected from the source files which have been sensed by using PhC sensors and detected by using Photonic crystal fiber (PCF) and AI techniques.

B. BIOLOGICAL SENSING

Biological sensing, similar to other sensing principles follows the Bragg's law [12] (1).

$$m\lambda = 2D(n_{eff}^2 - sin^2\theta)^{1/2} \quad (1)$$

where, m is the order of diffraction, λ is the wavelength, D is the distance between atoms in crystal, n_{eff} is Effective refractive index.

C. DATA ANALYSIS

Figure 1 shows the analysis in the variation of distance and or in the effective refractive index induces an alteration in the waveguide of reflected light in sensing region [13]. Figure 1 indicates variation of effective refractive index due to stimulus such as absorption of chemical and biological species or change in d. The biological sensors [14] show the stimulus changes in optical refractive index or the variation in structure. It can be seen by changing colors and observed by reflectivity or transmitivity measurement [15]. Different kind of hydrogels [16] can be employed for the detection of defected biomolecules. Photonic crystals sensors based on wavelength shift [17] are designed to operate in terms of sensitive to effective refractive indexes n_{eff} between infected cells and normal cells [18].

This paper is divided into four sections. First section entitled as introduction, discussed the introduction about optical fiber, photonic crystal fiber, methods, sensing principles etc. Next section indicates about tumors and its classifications. The next section will cover information about proposed dual core PCF refractive index based sensor for detection of tumor. In the next section use of AI algorithms to detect tumors and AI impacts on detection is explained. For this purpose various AI algorithms are used and the optimized result is displayed.

D. TUMORS & ITS CLASSIFICATION

Tumors are thought to arise when certain genes on the chromosomes [19] of a cell are damaged and no longer function properly. These genes normally regulate the rate at which the cell divides. According to National Brain Tumor Society (NBTS) [20] there are more than 120 different types of tumors identified. Some tumors like Glioblastoma Multiforme (GBM) [21] are malevolent and may be fast-growing while the different types of tumors like Meningioma, may be slow-growing and are compassionate. GBM is an aggressive type of Central Nervous System (CNS) [22] tumor that forms on the supportive tissue of the brain and may appear in any lobe of the brain. On the other hand Meningioma usually founds in the cells of the membrane that surround the brain and spinal cord [23-24].

E. PROPOSED DUAL CORE PCF BASED REFRACTIVE INDEX SENSOR

A dual core PCF based refractive index sensor is proposed for the detection of tumor cells in human brain. Selecting silica glass as a core material for designing of proposed dual core PCF structure keeping diameter of the air hole as 1.2 μm. Elliptical air holes are used in the first layer with semi major and semi minor axis as 1.2 and 0.8 µm respectively. The pitch value (distance from one air hole to other air hole) is kept 2 µm (FIGURE 3).

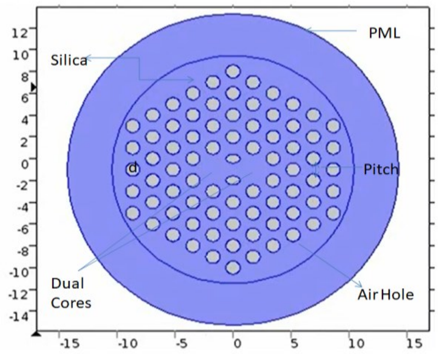
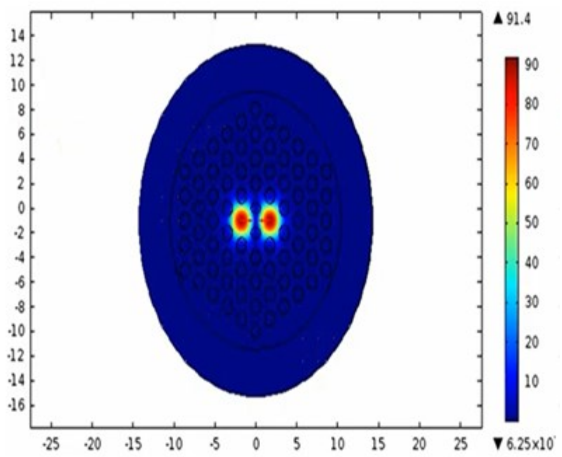
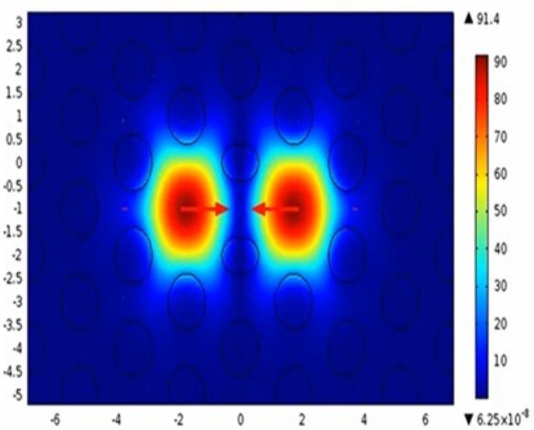


FIGURE 3. **Proposed Dual Core PCF**

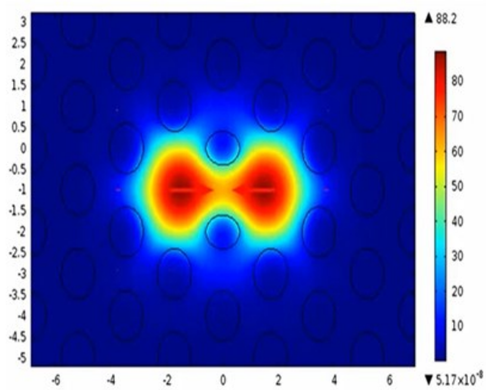
Perfect matched layer (PML) is included in the proposed structure to avoid the effect of reflected wave.



(a)



(b)



(c)

FIGURE 4. **(a-c) Samples Confinement for different values of Index Modes. It shows variation in refractive index and same time variation in sample confinement is observed**

Above figure shows that by varying the refractive index modes i.e., 1.4053, 1.4055, 1.4088, 1.41….., there is a variation in confining the sample through core of the proposed fiber. It is clearly indicating in FIGURE 4 (a-c). Samples taken from the liquid biopsy in terms of bio fluidic [25] is brought into the cavity of the PCF structure for detection of its confinement through core region. Here it is required to measures the refractive index of tumor samples to analyze it in efficient way. Refractive index is used to detect the variation in tumor cells. Refractive index based sensor is arranged in a setup to obtain transmission spectrum of tumor cell and normal cell. For this purpose a setup is arranged and shown in figure 6. It consists of an optical source (OS), optical fibers (OF), optical spectrum analyzer (OSA), polarization mode controller (PMC), 3dB coupler and optical detector (OD) to detect the variation in refractive indexes of various cells [26]. Proposed PCF based refractive index sensor is connected in between optical fiber and OSA. Optical source generates a light-beam which is used to split by 3dB coupler. These splitted beams create phase difference which can be detected and analyzed. The polarization mode controller (PMC) is used to adjust the polarization [27], if occurs during analysis.

The refractive index of silica at selected wavelength region i.e. from 1.5 µm to 4 µm can be calculated by Sellmier's equation (2) [28].

$$n^2\text{-}1 = \sum \frac{Ai\lambda^2}{(\lambda-\lambda i)((\lambda+\lambda i))} \quad (2)$$

where n is the refractive index and λ is wavelength.

The tumor cells can be sensed by using samples of infected cell into the air cavity [29], as the variation in the wavelength is sensed the energy coupling and energy transfer is observed (FIGURE 5). PML restricts the reflected stray energy [30].

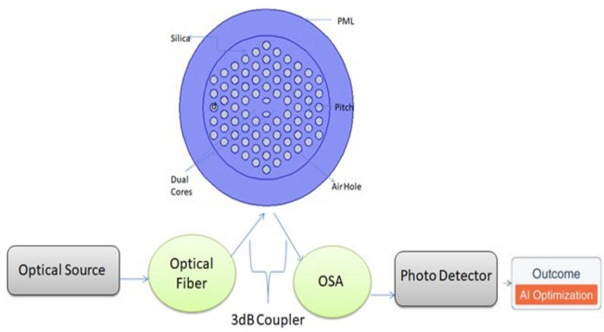


FIGURE 5. **Setup arrangements with proposed PCF sensor**

Depending upon the refractive index of different samples, the intensity of light [31] is modulated and detected at other end of PCF [32]. Sensitivity can be obtained by using the equation (3).

$$r_f = f\left(\frac{n_r}{n_c}\right) \tag{3}$$

Where n_r is the refractive index of the fluid, n_c is core refractive index, r_f is relative sensitivity coefficient and 'f' is the ratio of optical power with in large holes to the total power [33] which is given as (4)

$$f = \int[(E_x H_y - H_x E_y)\ _{samples}\ / \int[(E_x H_y - H_x E_y)]\ _{total} \tag{4}$$

F. ARTIFICIAL INTELLIGENCE ALGORITHM HELPS TO DETECT TUMORS

A brain tumor is a mass of abnormal cells [34] that grow in the brain. Early detection is crucial to improve patient prognosis [35], and thanks to new imaging techniques and artificial intelligence algorithm that can help doctors accurately identify these tumors.

Photonic integrated circuits [36] have enabled ultrafast artificial neural networks, providing a framework for a new class of information processing machines [37]. Algorithms running on such hardware have the potential to address the growing demand for artificial intelligence in tumor detection. Neuromorphic photonics [38] offers sub-nanosecond latencies [39], providing a complementary opportunity to extend the domain of artificial intelligence.
Here in this next section from the available variety of AI techniques, some of the selected algorithms such as support vector machine (SVM) [40], logistic regression (LR), fuzzy logic (FL) [41], random forest (RF), artificial neural network (ANN), and K-nearest neighbor (K-NN) [42] have been presented here in this paper.

Support Vector Machine (SVM) is an asymmetrical identification of structure-based minimization [43] of possibility and a classification of linear and non-linear statistics datasets. The intention is to discern an agitated hydroplane within an N-dimensional space (Where N is the number of attributes) that predominantly classifies the statistics data points. By mean of these support vectors it exploits the edges of the classifier [44]. It shows accuracy about 96%.

Logistic regression (LR) is a commanding and well-entrenched technique [45] for supervised classification. Logistic regression uses 5-nearest neighbors or 10-nearest neighbors. Bundling unites the design of ensemble learning [46] and bootstrap aggregation or bagging and has been found to generate advanced results. A bootstrap samples are taken from the training dataset and the out-of-bag samples are used for training the chosen ensemble of learners. To make use of the LR in terms of a binary classifier, a porch has to be allocates to differentiate two classes. It shows accuracy about 88%.

Fuzzy Logic sets employ diverse rules for mean standard deviation (MSD) [47] of attribute values. These rules depended on fuzzy division of overlapping areas and obtained accuracy around 93%.
The random forest (RF) is a group classifier [48] and consisting of numerous Decision Trees related to the means that a forest is a collection of countless trees [49]. RF algorithm believes the outcomes from numerous special Decision Trees, it can decrease the discrepancy resulted from the deliberation of a single Decision Tree for the similar dataset. The size of the trees was controlled by varying the minimum proportion of observations allowed in the terminal nodes of the trees [50]. Obtained accuracy is around 90%.
Artificial neural networks (ANN) with back-propagation error method [51] were feed-forward nets with one or more layers of nodes between the input and output nodes. ANN presents a system for the diagnosis and classification of tumors from MRIs [52] by using a back propagation network and obtained different accuracy rates like 77.56%, 72.5% and 95%.

K nearest neighbor (KNN) is a simple supervised classifier [53] that provides good efficiency for optimal values of K. Moreover, in KNN, training is extremely fast and any learning task is easy. KNN applied on MRI images presented the lowest accuracy of 70% when the amount of neighbors was selected as 7 (FIGURE 6 and 7).

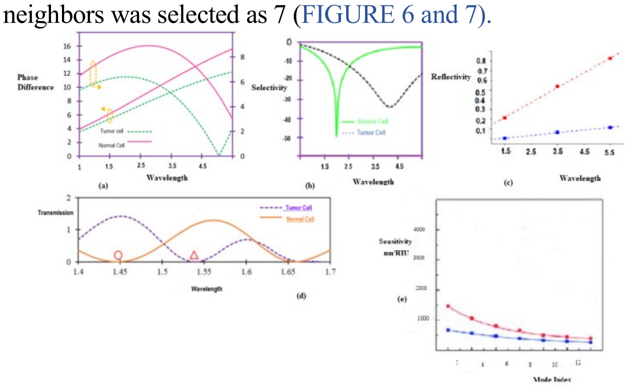


FIGURE 6. **Parameters (a) phase difference; (b) sensitivity, (c) reflectivity, (d) transmission and (e) sensitivity measured with wavelength variation for arranged setup and proposed PCF.**

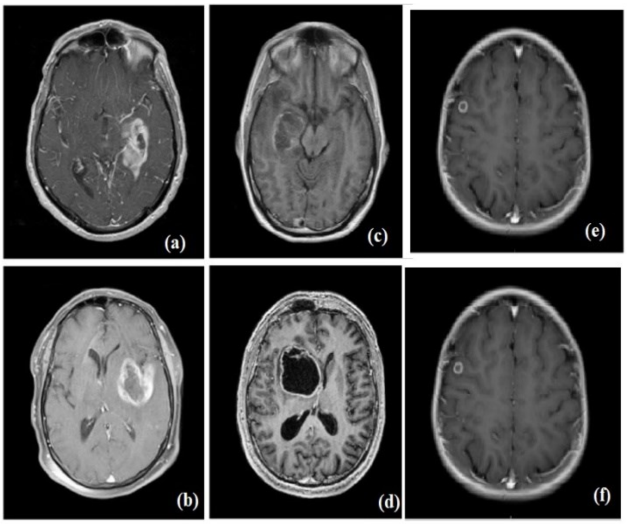


FIGURE 7. Tumor detection using various AI algorithms

After applying these above mentioned algorithms on all images in the database, we compute the sensitivity recognition statistics:

$$Sensitivity=\frac{Identified\ true\ positive}{Real\ no.of\ positiveses} \quad (5)$$

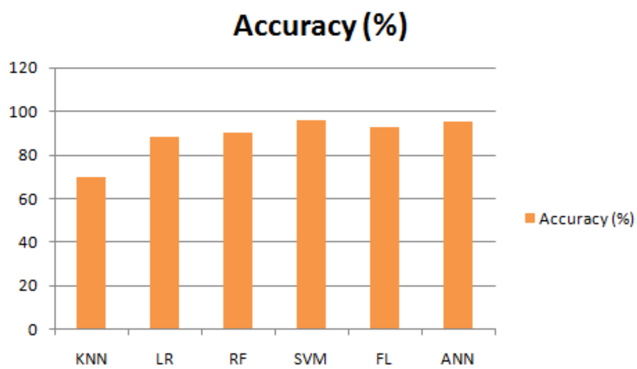


FIGURE 8. Performance of various AI techniques adopted for tumor detection

Various investigations have been done by mean of AI techniques in the chore of distinctive between different classes of tumors. The computer illustrates the apprehensive region or laceration and calculates approximately its probability of occurrence in the identified region (FIGURE 8).

III. RESULT

AI algorithms used to find out the accuracy, sensitivity, selectivity on basis of refractive index changes for normal cells and tumor cell. Maximum sensitivity observed as 32358 nm/RIU and the minimum sensitivity observed as 11258 nm/RIU. On the other hand the highest accuracy reported for SVM as 96% and minimum accuracy with KNN as 70%. Refractive index for tumor cells varies from 1.3342 to 1.4251.

IV. DISCUSSION

Earlier the obtained result shows tumor detection capabilities on individual basis. It was not associated with PhC sensing. With the help of PhC sensing we have obtained higher sensitivity and higher accuracy. The aim was to design dual core PCF based refractive index sensor to achieve high sensitivity towards tumor detection. For this purpose the proposed design is arranged in a manner in which tumor cell cavity is infiltrated in cladding region. To achieve optimized sensitivity various AI algorithms have been classified on basis of suspicious region detection. It has been observed that various optical characteristics like refractive index, phase difference, transmissivity and loss can be used to sense infiltration values in between normal cells and tumor cell. The change in refractive index leads to the shift in loss spectrum which is shown in above figures. Number of layers can be varied for the variation in the obtained results. The transmission spectrum represents that the wavelength of significant peak is enhanced with increasing RI of tumor cell.

In 2018 RCNN Technique were used and it shown an accuracy of 91 %, while sensitivity were observed as 90 %. Similarly in the same year CNN and Transfer learning offered an accuracy and sensitivity which were not up-to mark. CNN-DW offered accuracy and sensitivity as 81.83 and 83.34 respectively. As compare to these results our results are best suited for tumor detection.

Limitation of these techniques is that they will be suited and offer refractive index of tumor cell along with the photonic crystal sensors only, while higher accuracy and sensitivity can be obtained by implication of these AI techniques along with photonic crystal sensors. TABLE 1 indicates various refractive index values, accuracy and sensitivity of tumor cells and normal cells along with identified AI algorithms.

TABLE 1
Refractive index, sensitivity, accuracy and concentration of normal cell and tumor cell.

ML	Concentration (%)		RI		Sensitivity (nm/RIU)	Accuracy (%)
	GBM	Mening-ioma	Normal Cell	Tumor Cell		
SVM	76.30	57.20	1.38	1.4251	32358	96
LR	67.83	42.74	1.33	1.3955	30534	88
FL	71.48	49.36	1.34	1.3924	31435	93
RF	69.35	48.71	1.36	1.3521	31078	90
KNN	50.48	41.58	1.32	1.3437	11258	70
ANN	73.37	52.36	1.35	1.3342	32045	95

It defines that GBM tumor have more concentration as compared to meningioma. The various concentration values observed by different AI algorithms are presented with sensitivity and accuracy variation (FIGURE 9).

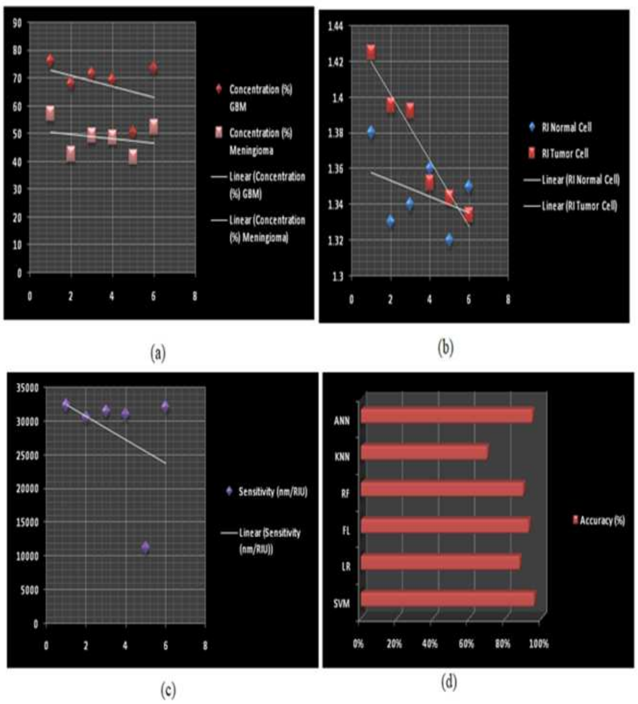


FIGURE 9. **Analyzed outcomes (a) concentration (b) Refractive Index (c) sensitivity (d) accuracy of normal and tumor cell by mean of various AI algorithms**

V. CONCLUSION

The aim of this study is to utilize Photonic crystal (PhC) sensors with the use of AI for tumor detection. It has been achieved. Photonic crystal (PhC) has been utilized due to their generous structures and flexibility to undergo with every field. Dual core PCF refractive index sensor is designed with selected diameter, pitch value and silica glass to achieve the identified goal. The goal was to improve the performance like sensing ability, accuracy, transmissivity and selectivity by using identified AI algorithms. KNN, SVM, ANN, FL, RF and LR are used to observe sensing ability and by selecting these algorithms accuracy and concentration of normal cells, GBM and Meningioma is calculated. It is found that tumors cell have refractive indices between 1.3342 to 1.4251. Maximum sensitivity observed as 32358 nm/RIU and the minimum sensitivity observed as 11258 nm/RIU. The highest accuracy reported for SVM as 96% and minimum accuracy with KNN as 70%. In summarize the PhC where working as sensor for detection of tumors is performing their outcomes on basis of refractive index. But with the integration of AI, they are performing in much better way and producing outcomes in better way while it comes in terms of accuracy, sensitivity, concentration etc. So it is concluded that AI shows their impacts on sensing and detecting tumor cells in better manner. In future the selection of PhC material, structure size, parameters selection can be varied along with PCF sensor to get different outcomes in different manner.

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Declaration

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