Photonic Crystal Tweezers For Tumor Detection Using Artificial Intelligence

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ABSTRACT: This paper is proposed for early tumor detection by photonic crystal tweezers with the use of a support vector machine (SVM) and artificial intelligence (AI)-based K-nearest neighbor (KNN) technique. Tumors are very serious and can cause more serious problems with human cells when infected. Previously, photonic crystal tweezers were used to detect tumor cells and proved very effective in many types of tumor detection. Among different AI techniques like K- nearest neighbor (KNN), Adoptive Neuro Fuzzy Inference System (ANFIS), Fuzzy KNN (FKNN), Support Vector Machine (SVM) and probabilistic neural network (PNN); SVM and KNN observed accuracy of 96% and 92% respectively while the sensitivity is important observed by these two techniques are 32,358 nm/RIU and 11,258 nm/RIU was observed to be 1.251 and 1.337 for tumor cells, respectively. Majorly the research is supposed to offer advantages early detection of infected tumor cells by implication of tweezers with AI.

Keywords: Electronic materials, Sensors, Artificial Intelligence, Photonic crystal tweezers, Tumors.

INTRODUCTION

Photonic Crystal tweezers [1] are used in non-invasive [2] manipulation for nano-particles in medicines to identify infected cells from Deoxyribonucleic acid (DNA) or sperm cells [3]. They trap nano particles by using laser light. The trapped particle position can be controlled by varying the focus of the laser light with an objective lens of high numerical aperture (NA). Due to the transfer of momentum from the scattering of incident photons [4], dielectric particle near the focus experiences a force. Earlier it was used as for diagnosis of infected cells, but with the implementation of AI it can also be used for early prediction and diagnosis of these tumorous cells present in human body. This is the major advantage of this research.

Photonic Crystal Tweezers

It uses Gaussian beam laser to provide an inhomogeneous electromagnetic field which generates Lorentz force and scattering force [5]. A parallel beam of light with a gradient in intensity incidents on a spherical particle. The refraction trace of two representative rays is obtained and their linear momentum change after refraction [6]. Resultant of all rays pulls the sphere towards to region with higher intensity, which is the focus of the Gaussian beam laser [7]. To make Photonic Crystal tweezers appropriately Spatial Resolution as 0.1-2nm, Probe Size as 0.25-5 μm and Force Range of 0.1pN to 100 pN have been utilized. The fundamental principle behind Photonic Crystal tweezers is the momentum transfer associated with bending light. Light carries momentum that is proportional to its energy and in the direction of propagation [8]. Any transform in the course of light, by reflection or refraction, will consequence in a transform of the momentum of the light. If an object bends the light, changing its momentum, conservation of momentum requires that the object must undergo an equal and opposite momentum change. This gives rise to a force acting on the object [9].

Materials and Methods

Tweezers are majorly used for the detection of tumorous or infected cells. It works on the Gradient force F_{grad} and Scattering force F_{scat}. Earlier lenses were used in these detection techniques which make it more complicated, So Optical fibers have been utilized in place of these lenses as core materials.

Tumor Detection by Tweezers

In several red blood cells (RBSs) or blood vessels [10] it is complicated to control elements positioned in a contracted location owed to low incorporation of conformist Photonic Crystal tweezers (PCTs). The micro-elements positioned in close proximity [11] to the lean of the fiber will be incarcerated by the "longitudinal gradient force (LGF)" onto the optical axis of the fiber as well as subsequently captured through "lateral gradient force" at the focus of the emitted light or shift by the side of the optical axis underneath the exploit of "optical scattering force" (OSF) [12]. By utilizing optical fibers (OFs), optical tweezers can be fabricated which are additionally stout and around hundred times smaller than conventional adaptation. It can be introduced into a blood vessel to entrap individual cells [13].

To make the early diagnosis device smaller, lighter, and more portable [14], replace the lens with glass optical fibers. For tumor cell detection, mechanical properties of a single tumor cell are quantified by using Single-Beam Acoustic Tweezers (SBAT) [15], a non-contact assessment tool using a focused acoustic beam. Cell-mimicking phantoms and Agarose Hydrogel Spheres (AHSs) [16] served to standardize the biomechanical characteristics of the cells.

Tools and Techniques

The techniques used for detection of tumor cells offer a sequential process which includes early diagnosis with the help of suitable AI techniques thereafter detection of these infected cells with the help of tweezers. Support Vector Machine is a linear model for classification and regression problems. It can solve linear and non-linear problems and work well for many practical problems. Support Vector Machine (SVM) is an asymmetrical identification of structure-based minimization 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.
K-NN classification rule (Mahajani) is one of the most well-known and widely used nonparametric pattern classification methods. K-NN is a simple supervised classifier that provides good efficiency for optimal values of *K*. K nearest neighbors (KNN) is a simple, straightforward classifier, which can provide good performance for the optimal values of K. in addition, KNN training is very fast, and every game mission is very simple.

SBAT principle

Particles with diameters smaller than the wavelength can be trapped by SBAT in the Rayleigh regime. It is observed that Rayleigh scattering [17] is suitable for small particles (radius < 0.4λ). Generally both kinds of forces subsist in an optical trap, and the restoring force field is the consequence of the balance of the two. For a Rayleigh sphere of diameter dp, this force can be formulated as

$$F_{scat} = \frac{10\sigma}{c} nm \quad (1)$$

and the scattering cross-section σ of a Rayleigh particle is given as:

$$\sigma = \frac{2\,\pi^5 d_p^6}{3\lambda^4}\left(\frac{n_p^2 - n_m^2}{n_p^2 + 2n_m^2}\right) \quad (2)$$

where

I_0 = Intensity of incident laser,

n_p and n_m = Refractive Index of the particle and the surrounding medium respectively,

c =The speed of light in vacuum and

λ = wavelength of trapping laser.

In addition to the scattering force, a polarized particle in an inhomogeneous electric field [18-22] experiences a gradient force, which is proportional to the optical intensity gradient:

$$F_{grad} = \frac{2\pi\alpha}{cn_m^2}\nabla I_0 \tag{3}$$

Where

$$\alpha = \frac{n_m^2 d_p^3}{8}\left(\frac{n_p^2 - n_m^2}{n_p^2 + 2n_m^2}\right) \tag{4}$$

is the polarizability of the particle.

Results and Discussion

As the trapping is performed Black dotted circle observed which indicates equivalent trapping position. It defines trapped tumor cells and trapping zone. These trapped tumor cells have been observed with Single-Beam Acoustic Tweezers and variation in the observed trapped tumor cells.

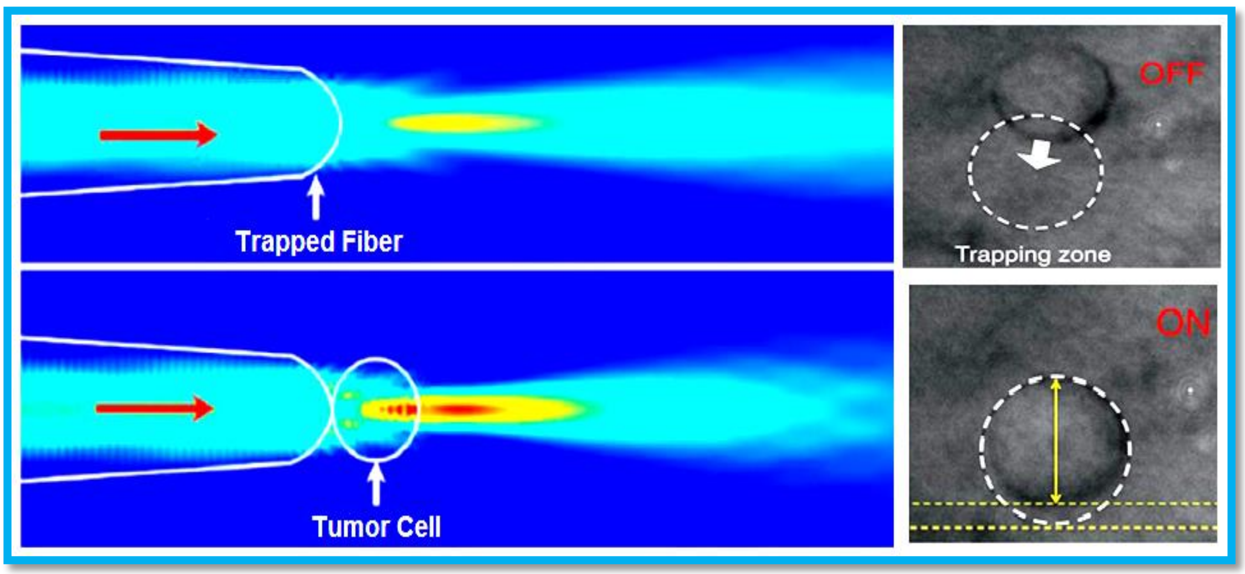

Figure: 1 Trapping Tumor Using Photonic Crystal Tweezers

Cell detection with respect to time and its intensity variation is also observed in figure 1 which represents that it is quite useful device to detect infected tumor cells. 3D plot of its Refractive index variation of tapered cell with respect to wavelength is also obtained. Since photonic crystal tweezers are best suited for non-invasive nano particles or infected cells. So it is observed that deformation in cells is simply an indication of infection. This deformation may be observed by trapping of cells by using tweezers.

Table: 1 Observation of AI algorithms in terms of Accuracy, Sensitivity and Refractive Index with Training and Test dataset

Parameter	**Data Set**	**SVM**	**KNN**
Accuracy (%)	Training	97.45	95.34
	Test	96	92
Sensitivity (nm/RIU)	Training	33452	12021
	Test	32358	11258
Refractive Index	Normal Cell	1.38	1.32
	Tumor Cell	1.4251	1.3437

On the basis of this obtained data set below mentioned outcomes have been observed which is presented in below figure 2.

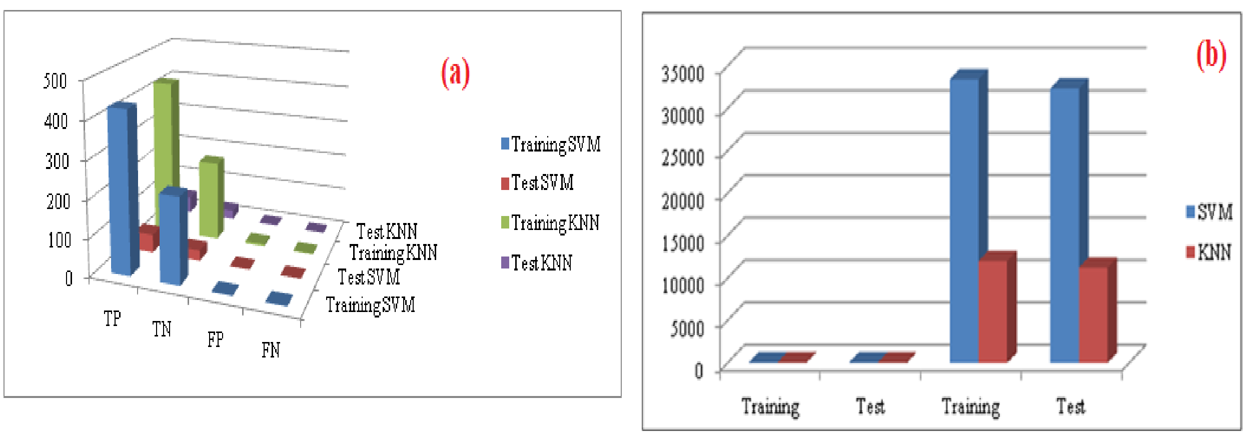

Figure: 2 (a) Analyzed confusion matrix of Training and Test data set and

(b) Accuracy and Sensitivity using SVM and KNN

It is found that sensitivity observed by using SVM and KNN is 32358 nm/RIU and 11258 nm/RIU respectively, whereas the refractive index obtained for normal cell is 1.38 and 1.32 respectively for SVM and KNN and for tumor cells it is 1.4251 and 1.3437 respectively for SVM and KNN

CONCLUSION

Optical tweezers have become a critical tool for scientists to perform experiments at the molecular and cellular scales. Since they can trap small objects and hold them in place, away from contact with anything that could alter their state or function, the tweezers allow materials or individual cells to be studied without removing them from their native environments. It uses optical trap and the restoring force for trapping and identification of infected cells. With the implication of AI it is also offering great outcomes in terms of early diagnosis of such cells so that patient can be saved before critical damage and can be offered best medication. Here SVM and KNN have been proposed with photonic crystal tweezers to offer greater accuracy as 96% and 92 % respectively.

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