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Original Article

Deep Derma Scan: A Proactive Diagnosis System for Predicting Malignant Skin Tumor with Deep Learning Mechanisms

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Abstract - *The transformation in DNA due to the continuous, unprotected exposure to ultraviolet rays and high toxic chemical management in occupational settings causes skin cancer in general. There exist two major types of skin cancer, namely melanoma and non-melanoma. The basal carcinoma and squamous carcinoma are categorized under the non-melanoma type of cancer. As per the recent statistical report by the world cancer research fund of the American institute of cancer research, melanoma skin is attributed as the nineteenth most commonly occurred cancer irrespective of age and gender worldwide. Also, it reveals that non-melanoma is the fifth most prevalent skin cancer worldwide, but it is less likely to grow, spread and be treatable. The early identification of the malignant skin tumor with periodic treatment increases the survival rate of melanoma patients. The initial screening and regular monitoring reduce the risks of becoming benign into a cancerous cell. The existing solutions are profound in this area, as mobile applications are insufficient to prove their accuracy in diagnosing. They missed out on large cases as unpredicted, even the physical examination by doctors. The deep learning technologies will enhance the performance of accurate prediction of malignant tumors in advance. In this work, an optimized deep neural network model is developed to predict skin cancer and evaluated against the most prevalent machine learning models.*

Keywords - *Deep learning, Image processing, Malignant tumor, Proactive diagnostic system, Skin cancer.*

1. Introduction

A trusted internet survey made in 2018 states that in the total of 18.1 million new incidences of skin cancer, 9.6 million deaths are caused because of this around the globe. The European epidemic study mentioned that the incidence rate of melanoma would go as high as 40-50/100000 population shortly. Moreover, melanoma and other types of skin cancer seek attention in preventive solutions as per the result of a systematic review conducted by the global health sector. Likewise, the trends observed in skin cancer confirm the essence of an effective diagnosis system.

The artificial intelligence solution for the healthcare industry improves the accurate diagnosis without much intervention from the clinician. In the future, the physical consultation with the medical expert would be greatly reduced as the devices around the environment are designed to perceive the patient data, processing on time and prompt necessary actions without any delay. Today's smartphones provided with storage and computation facility strengthens the application developers in bringing the effective diagnosis model within the palm of the individual. A few mobile applications exist that examine the potential presence of melanoma skin by taking pictures using a camera provided, thereby necessitating physical evaluation of dermatologists in practice. But the accuracy of the applications still needs a revision by empowering the same with technological giants such as artificial Intelligence.

The scientists at Stanford University successfully brought an effective diagnosis system by using deep learning techniques. With the help of convolutional neural networks (CNN), an optimal solution for melanoma skin cancer is achieved. Sebastian Thrun, an adjunct professor at Stanford artificial intelligence laboratory, built a diagnostic tool based on deep CNN to classify susceptible skin tissues. The attempts to bring diagnostic systems for skin cancer are suffering from the following shortfalls listed below.

- Focuses on specific category, i.e. melanoma in the study; other kinds are left out in registries itself
- Works on datasets collected from international and national repositories
- Utilizes machine learning algorithms in attaining better accuracy in prediction

Moreover, the mobile applications and web services devoted to this area need to address a secured central storage system for data storage and analytics processing instead of acting as either an educational portal or a consultation service. The accuracy and reliability of the system are also enhanced with current technological jargon in addressing effective solutions to skin cancer problems.

2. Related Work

Akila Victor et al. [1] reviewed and summarized existing techniques in detecting skin cancer by highlighting remarkable past efforts. Muhammad Ramzan et al. [2] investigated deep learning techniques for skin cancer detection and summarized significant techniques and efforts in the article. Mohamad Goldust et al. [3] and Bingsheng Huang et al. [4] deeply analyzed the role of machine learning in bringing an automatic diagnostic system for skin cancer.

Shivangi Jain et al. [5] designed a skin cancer detection system by applying image processing mechanisms. Upon acquiring the image, the system used automatic thresholding for masking RGB values for image segmentation. The geometric features aligned with the Asymmetry, border, colour and diameter (ABCD) rule of dermoscopy in real practice were exercised in the feature extraction module of the system. The computer-assisted diagnostic tool was developed to serve the public in rural areas who found difficulty in making physical consultations.

Esperanza Guerra-Rosas et al. [6] implemented a spectral technique to diagnose cancerous skin spots. This model uses the following three spatial filters to obtain effective spectral index calculation: classic, inverse and k-law nonlinear filter. The result exposed 95.4% accuracy in detecting the cancerous melanoma cell.

Uzma Bano Ansari et al. [7] brought an early skin cancer detection model empowering with image processing and machine learning algorithms. The model was used with a thresholding algorithm for segmentation, gray level co-occurrence matrix (GCLM) method for feature extraction and support vector machine (SVM) for classification. Praveen Banasode et al. [8] designed a skin cancer detection system using SVM. After applying pre-processing like the RGB-to-Grey scale and HSV, SVM is exercised to detect melanoma skin. The system produced 96.9% accuracy over the images taken from the ISIC archive.

Ulzii-Orshikh Dorj et al. [9] devised CNN based classification approach to deciding the cancerous cell. The system had its high focus on the classification part and modified the existing AlexNet architecture to extract features of image collection taken from the internet. The experiment results provided the average accuracy rate in predicting the major kinds of skin cancer as 95.1%

Dascalu et al. [10] analyzed the significant role of deep learning in predicting skin cancer and built a classification model annotating sound waves to attain better accuracy. Patient's biopsy reports were fed as input to the CNN classifier and enriched with sonification techniques to predict cancerous cells, among others. Shwetambari Borade et al. [11] designed a skin classification system to compete with CNN performance by exploiting wavelet transforms, scattering networks and residual networks.

Nadia Smaoui Zghal et al. [12] developed a simple, computer-assisted method for diagnosing skin cancer. The system employed median and morphological nonlinear filters for image segmentation, the ABCD rule for feature extraction, and the classification finally provided total dermatoscopic value calculation (TDV). The experiment results of the system revealed the overall accuracy rate as 90%. Nitin Pise et al. [13] developed a computer-aided skin cancer prediction system aligned with the existing model.

Jinen Daghrir et al. [14] devised a CNN-based classifier to examine the lesion for its potential to become malignant spots in the skin. The efficiency of the proposed method was evaluated against two common artificial neural network algorithms: K- nearest neighbor (KNN) and SVM. The proposed method outperformed the algorithms taken for evaluation and facilitated the accuracy of 85.5% as a whole. Melika Hamian et al. [15] developed a thermal exchange optimization-based neural network classifier for detecting skin cancer and achieved 92.65% overall accuracy. In work proposed by Krishna Monika et al. [16] in detecting skin cancer cells, ABCD and Gray Level Co-occurrence Matrix extract statistical and textural features (GLCM). The experiment is based on the ISIC 2019 Challenge dataset, which includes eight different forms of dermoscopic images. The Multi-class Support Vector Machine (MSVM) was used for classification, and the accuracy was around 96.25.

Mohammad Ali Kadampur et al. [17] designed architecture to predict melanoma spots using deep learning algorithms with great interest. The deep learning studio (DLS) was selected as an implementation medium and emphasized the same features in a detailed context. DLS is a non-programming tool that hinders the novice person from learning all about deep learning easily as a graphical guide. The smartphone applications that are available for detecting skin cancer [18] are as follows:

- UMSkinCheck – is a free application designed by the University of Michigan that promotes self-examination and tracking functionality over some time by creating a mole library
- Mole Mapper – developed by Oregon Health & Science University, keep track of mole and change over time by taking snapshots of the same
- Miiskin – application enables users to track their mole and assess the potential to become cancerous cell with optimal payment

- Molescope – application makes use of a high-resolution camera to detect cancerous skin cells in the early stages
- Skin Vision – identifies high-risk spots by classifying them into high or low-risk tumors and facilitates recommendations about what to do next.

Jiasui et al. [19] presented the digital screening process, which helps to predict cancerous cells in their early stages. Person et al. [20] elaborated on the contribution of vitamin D in the sun screen lotions and brought the same as a product to eliminate the effects of exposure to UV rays observed from the sunlight. Kenet [21] designed a server-based diagnostic system that processes user requests to detect skin cancer via the server, which acts as a central repository in its design.

3. Background Details

The lower diagnostic accuracy for cancerous skin cells is the primary reason for devising an over-treatment (caused by a false positive diagnosis) or an under-treatment (caused by a false negative diagnosis). False positive diagnosis leads to unnecessary biopsy procedures with pathological examinations, which are painful and increases the treatment cost. There exist several imaging techniques that reduce the effect of false positive diagnosis mentioned above and are listed below:

- Reflectance confocal microscopy
- Optical coherence tomography
- Ultrasound
- Dermoscopy

Visualizing skin lesions by any of the above-mentioned high-resolution imaging techniques is not sufficient to differentiate malignant tumours from benign. There arises a need for reproducible diagnosis mechanisms practiced by medical experts like dermatologists in examining and evaluating skin cancer types. In practice, there are four frequently used reproducible methods for the diagnosis of skin cancers and those enlisted below.

- ABCD-E rule
- The 3-point checklist
- The7-point checklist
- The Menzies' method
- Pattern analysis

The ABCD criteria (except E), their possible scores and relevant interpretations are tabulated below and presented in Table 1. The formula to obtain the total dermoscopy score (TDS) in detecting cancerous skin spots is specified as Equation 1and is formulated with the help of weight factors.

$$TDS = (AScore \times 1.3) + (BScore \times 0.1) + (CScore \times 0.5) + (DScore \times 0.5) \quad (1)$$

Table 1. Significant Features of ABCD

Criteria	Possible Score	Description	Weight factor	Total Dermoscopy Score (TDS)	Interpretation
Asymmetry	0-2	Assess contour, color and structures	1.3	< 4.75	Benign lesion
Border	0-8	The abrupt ending of the pigment pattern	0.1	4.8-5.45	A suspicious lesion, close follow-up or excision recommended
Color	1-6	Presence of max 6 colors (white, red, light brown, dark brown, blue-gray, black)	0.5	>5.45	High possibility of melanoma
Dermoscopic Structures	1-5	Presence of network, structureless areas, streaks, dots and globules	0.5	False-positive score (>5.45) sometimes observed in	Reed and Spitz nevus Clark nevus with globular pattern Congenital melanocytic nevus

4. Deep Derma Scan: Proposed Model

The proposed system is planned to offer a fruitful solution to serve skin cancer patients in saving their life by screening susceptible spots on the skin in its early stages. The application must be designed with a private cloud server to enable its functions. The significant phases of the proposed system are discussed as follows.

4.1. Deploying Data pre-processing

The first phase is Data pre-processing, through which data can be formulated to be ready for analytics. The proposed system is to be executed the following pre-processing functions that help facilitate optimal solutions.

- RGB-to-Gray Scale Conversion
- Filtering for removing noise – Median filters and histogram equalizers

- Filtering small elements like hair- Bottom hat filters and region filling morphology

4.2. Segmenting the input

In general, image segmentation aims to uncover the unique features of data considering the region of interest. Here it is proposed to reveal the cancer cells out of the input. In this phase, to improvise the quality of lesion images, the ABCD rule is combined with GLCM. The GLCM is a widely used statistical approach for extracting textural features from photographs. GLCM executes the calculation by considering two pixels at a time, the reference and surrounding pixels. It's defined using a matrix, in which the number of grey levels in an image corresponds to the number of rows and columns. The relative frequency matrix element P (i, j | Dx, Dy) is named after the intensities i and j, separated by a pixel distance Dx, Dy. There are 14 properties specified by the co-occurrence matrix, including energy, entropy, autocorrelation, correlation, homogeneity, and contrast. In this phase, to improvise the quality of lesion images, the ABCD rule is combined with GLCM.

4.3. Accommodating Intelligence using Deep Learning

The optimized input data are imported to the server to enable data storage and analytics. The machine learning techniques are exercised here to reduce the error rate in classification.

Deep learning algorithms like convolutional neural networks (ConvNets / CNN) recently gained attention because of their efficiency in mapping voluminous images within minimal execution time. The proposed model's CNN-based architecture for predicting skin cancer is depicted in Fig. 1.

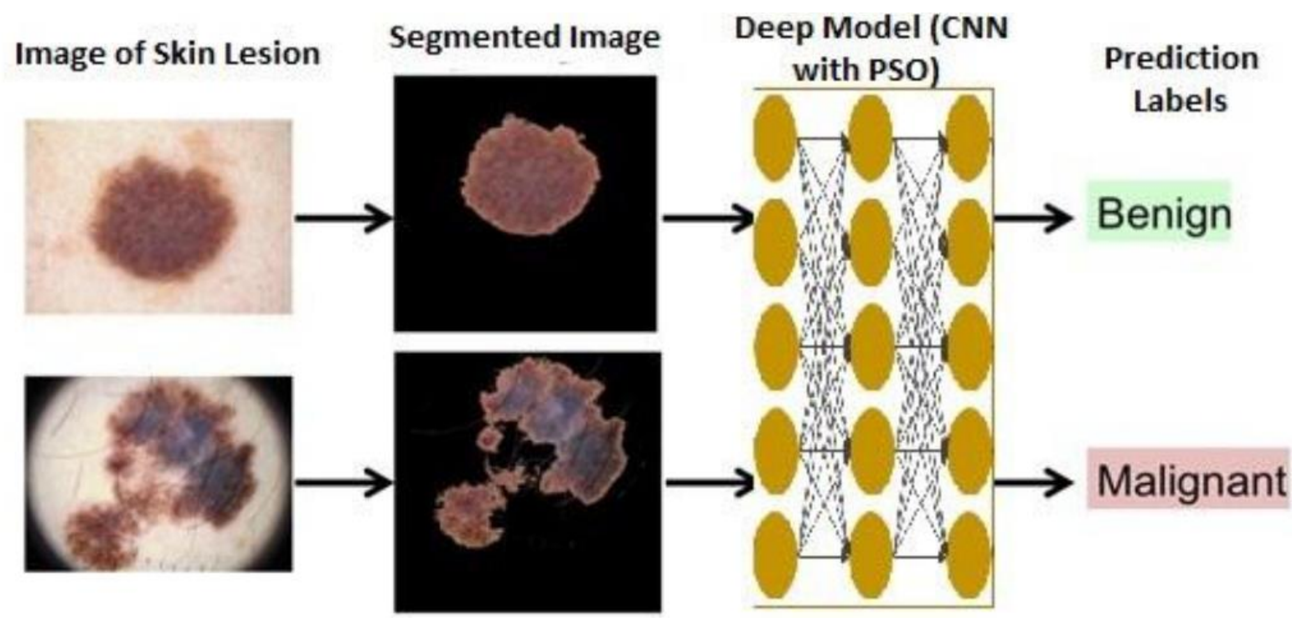

Fig. 1 CNN framework in detecting skin cancer

Furthermore, the particle swarm optimization (PSO) algorithm is applied herewith to improve the performance. PSO originates from the swarm behavior encountered in flocking birds or fish schooling. While comparing with other optimization algorithms, PSO is simple, easy to implement, adaptable to its control parameters and ensures computational efficiency. According to research conducted on PSO, it is highly utilized in the healthcare industry to predict diseases [22-24]. The process flow of PSO is presented in Table 2.

The effect of adding optimization into deep networks is well discussed in [25]. In that work, the teacher learning-based optimization (TLBO) algorithm is implemented to detect breast cancer from mammogram images. It is evaluated to produce higher classification accuracy than the others.

Table 2. Algorithmic steps in PSO

1) Initialize X_i and V_i such that $x_i \in rand(X^{min}, X^{max})$ and $V_i = 0$, where $rand(X^{min}, X^{max})$ is the uniform random number between X^{min} and X^{max} $(\forall_i = 1,2,\ldots,n)$
2) $\hat{X}_i \leftarrow X_i \; and \; \hat{g} \leftarrow \arg\min_{x_i} f(x_i)$ (2)
3) While not converged:
- For each particle:
  - Generate uniform random numbers
  - Update the velocities of each particle:

$$V_i^{k+1} \leftarrow wv_i^k + c_1 r_1 \left(\hat{x}_i - x_i^k\right) + c_2 r_2 \left(\hat{g} - x_i^k\right) \quad (3)$$

- Update the positions of each particle:
  $x_i^{k+1} \leftarrow x_i^k + v_i^{k+1}$
- Calculate $f(x_i)$
- Update the local bests: $\hat{x}_i \leftarrow x_i \; if \; f(x_i) < f(\hat{x}_i)$ (4)
- Update the global best: $\hat{g} \leftarrow x_i \; if \; f(x_i) < f(\hat{g})$ (5)

5. Results and Discussion

This section contains information about the dataset used as an input, the execution environment in which the proposed model was tried, and the performance metrics that were utilised to determine the work's efficiency.

5.1. Dataset Description

The International Skin Imaging Collaboration (ISIC) is a collaboration between academics and the industry that aims to make digital skin imaging more widely available to minimise melanoma fatality. The ISIC Challenges 2020 is exercised to detect melanoma. The dataset consists of 33,126 samples. The cross-validation strategy applied to evaluate the proposed model is 80:20.

5.2. Development Platform

To execute deep learning algorithms, the computing must be capable of doing so. The hardware requirements for implementing the proposed model are provided in Table 3. Anaconda is chosen as a programming language platform as it is popular, free and open-source. It is simple to install on any operating system, including Linux, Unix, Windows and Mac OS. It has around 1500 data science tools that may be used to build machine and deep learning models. The proposed model utilizes CUDA and cuDNN tools to develop the same.

5.3. Performance Metrics

The metrics used to evaluate the performance of the deep learning model for detecting skin cancer are listed below. Also, the formula to calculate the same is captured in Equations (6) to (8), respectively.

- Accuracy: Indicates the correctness of the system

$$Accuracy = \frac{T_p + T_N}{T_P + F_N + F_p + T_N} \quad (6)$$

- Sensitivity: Specifies the true positive predictions

$$Sensitivity = \frac{T_P}{T_P + F_N} \quad (7)$$

- Specificity: Gives the measure of true negative predictions

$$Specificity = \frac{T_N}{T_N + F_N} \quad (8)$$

The proposed deep learning model is evaluated against the classifiers like naive Bayes, KNN, SVM and CNN. The obtained result is in Table 4. The proposed approach provides better results because optimization (PSO) is executed over the CNN classification labels.

Table 3. System requirements

Hardware Requirements:
• Central Processing Unit (CPU): Intel Core i5- 2.9Ghz • Graphics Processing Unit (GPU) : NVIDIA GTX 960 • RAM: 8 GB
Software Requirements:
• Anaconda 5.1 • Python 3.6 • TensorFlow, Keras

Table 4. Performance analysis of proposed model

Methods	Accuracy	Sensitivity	Specificity	Positive Predicted Value	Negative Predicted Value
SVM	96.9	85.8	81.2	75.6	18.6
KNN	93.7	89.2	85.8	87.7	13.4
Naive Bayes	92.5	81	82.3	86.2	14.9
CNN	94.5	88.6	87.3	80.6	12.8
DCNN with PSO	97.6	87.2	81.3	88.5	10.8

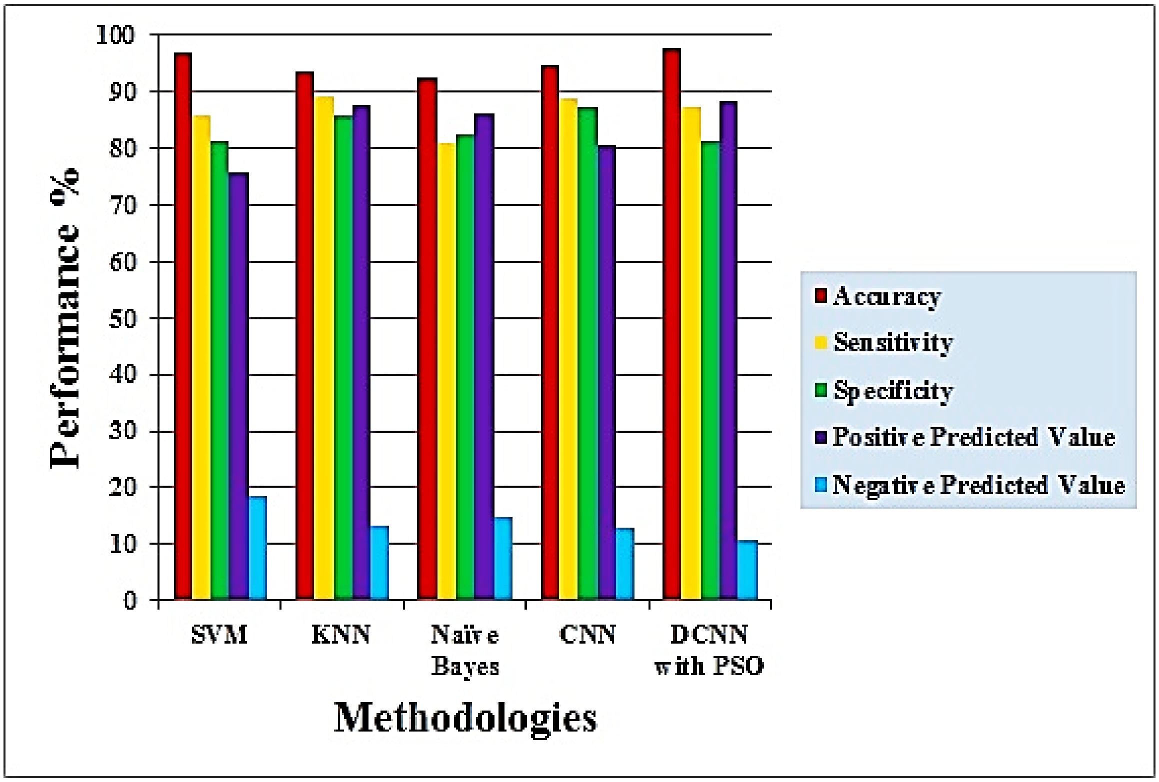

Fig. 2 Comparative analysis of proposed model

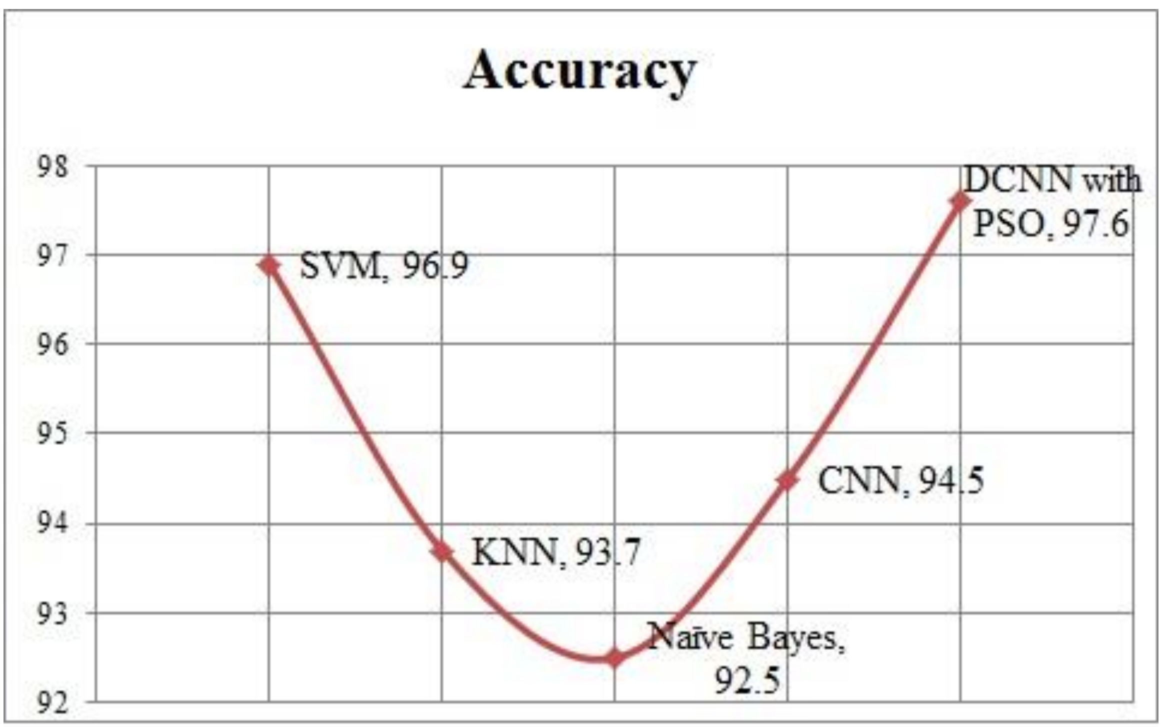

Fig. 3 Accuracy chart of the proposed model

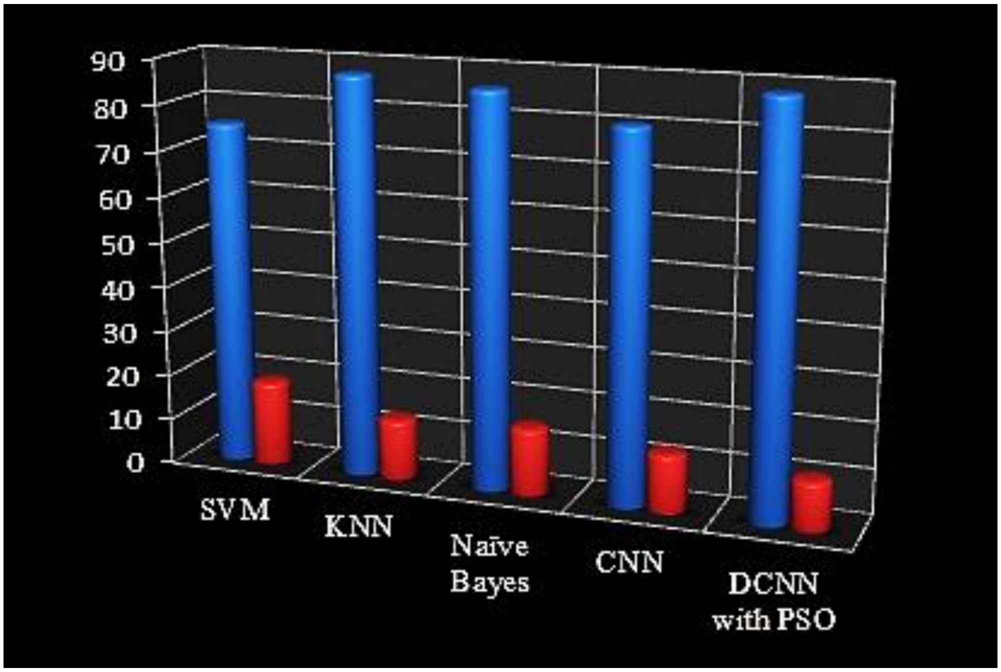

Fig. 4 True Prediction Vs. False prediction rate

In comparison with other classifiers, the proposed deep algorithm, which is empowered with PSO, enables its overall accuracy as 97.6%, as in Fig. 2. It is observed that the proposed deep learning model for skin cancer detection is 3.1% more accurate than classical CNN model, 5.1% accurate than naive Bayes, 3.9% than KNN and 0.7% than SVM as in Fig. 3.

As CNN is optimized with PSO in the proposed model, it exhibited a less negative prediction rate of 10.8% compared to other classification techniques and is mapped in Fig. 4.

6. Conclusion

The early diagnosis of the cancerous cell helps to increase the survival rate of the patients by providing appropriate treatments on time. This work builds a novel deep learning model by incorporating PSO with CNN architecture. The system's efficiency is assessed with the most experimented with classification algorithms like SVM, KNN, Naïve Bayes and CNN. The proposed model gives an overall accuracy of 97.6% and a less negative prediction rate of 10.8% than others.

Further, recurrent neural networks can be investigated to determine the recurrence rate of skin cancer.

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