International Journal of
INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING
ISSN:2147-6799 www.ijisae.org Original Research Paper

Predicting Scope for Survival Rate of Bone Metastases Patients with Deep Learning

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Submitted: 10/01/2024 **Revised**: 16/02/2024 **Accepted**: 24/02/2024

Abstract: Bone cancer exists in two forms namely primary and secondary. The primary bone cancers are the ones that grow from the bone cells. The secondary bone cancers are also known as metastasized which developed from other organs and penetrated into bone. The national cancer institute states that occurrence rate of primary cancer are found to be less than 1% and the secondary forms are the most common ones in its highest rate of occurrence. Predicting the various forms of metastases bone cancer early in advance mitigates the further growth of tissues and evacuation treatment plans reduces the miserable consequences and increases the survival rate of the patient. The proposed system aims to develop a preventive kind of medical service devoted to metastasized bone cancers with a help of an improvised Convolutional Neural Network (CNN). Further the efficiency of the proposed model is investigated against the most common learning algorithms like decision tree, k-nearest neighbor (KNN), logistic regression, and random forest.

Keywords: *Convolutional neural network, Deep learning, Metastasized bone tumors, Image processing, Predictive diagnosis, Wireless sensors*

1. Introduction

The skeletal system of human body is made up of 206 bones, responsible for enabling muscular activities like carry, sit, walk and run smoothly. Bone is composed of various tissues, calcium phosphate and minerals. The weakening in the structure like break down or growth of new bone leads to illness associated with bone. Whereas the uncontrolled mass generation in bone leads to cancer. The primary bone cancer which initiates from bone is accounted as uncommon ones. Moreover the cancer penetrated from other organs like lung, blood, liver and breast are the most vulnerable and known as metastasis.

While it can originate in whichever bone in the body, the most frequently afflicted are the pelvic or long bones in the arms and legs. Bone tumors are exceedingly rare; they account for less than 1% of all malignancies. In reality, benign bone tumors usually are outnumbered malignant ones in this regard. "Bone cancer" does not apply to cancers that originate outside of the bone and spread (metastasize) into it. Rather, those cancers are called after the site of their initial growth, for example, bone metastasis from breast cancer.

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Bone weakened, resulting in fracture, bone ache, tiredness, involuntary weight loss, soreness and swelling close to the injured area are the most common indicators of bone cancer. While adults are the primary target of some forms of tumors in the bones, children are the primary target of others. Although chemotherapy and radiation therapy are also alternatives, removal of tissue by surgery is the most common course of treatment. Treatment options for bone tumors can include chemotherapy, radiation therapy or surgery, depending on the type of tumor.

The previous attempts to introduce diagnostic systems for bone cancer had the following shortcomings, which are detailed below.

- Focuses on particular category of secondary bone cancer in the study
- Works on specific modality of input like X-Ray, computerized tomography (CT), Radio therapy (RT) and Magnetic Resonance Imaging (MRI)
- Makes use of machine learning technologies to increase prediction accuracy, still has its scope in modern deep learning exercises

The suggested model uses deep learning techniques to provide individuals who have metastatic bone cancer with an accurate predictive solution.

2. Related Work

Tanzila Saba [1] deeply investigated the role of machine learning in cancer diagnosis and cure care processes. He also enlightened the scope for initial screening in improving the survival of patients.

Nikolaos Papandrianos et al. [2] addressed the significance of bone metastasis. Here, the scintigraphy photos were used as the input. By examining the potential of convolutional neural networks (CNN), the system's performance yielded an overall efficiency of 97.38% accuracy.

Nikolaos Papandrianos et al. [3] attempted to build a robust CNN based architecture in detecting breast cancer via scintigraphy images of the patient. The same also employed to diagnosis the bone metastasis by taking whole body images as input and it yielded 92.50 % accuracy.

Khushboo Munir et al. [4] put forth remarkable effort in obtaining the effective and promising cancer diagnostic tools equipped with artificial intelligence. It is also enlisted the modern deep learning techniques to be considered while designing a prognostic solution to the cancer. Among all the system focused on CNN based implementation to reveal less computational cost with high accuracy.

Mogana Darshini Ganggayah et al. [5] proposed a survival analysis of breast cancer patients with real time data extracted during 1993 to 2016 from University Malaya Medical Centre, Kuala Lumpur, Malaysia. It was also shown how the random forest technique is used in this field.

Andrés Redondo et al. [6] designed a multidisciplinary approach in diagnosing the bone cancer with an aim to facilitate practical recommendations timely. The system highly focused on sarcoma and provided the necessary guidelines with treatment structure devoted to it according to the medical practices in real.

The efficacy of predictive machine learning methods in forecasting cancer patients' survival was examined by Azadeh Bashiri et al. [7]. In this model, an ANN based algorithms were used to recognize unique contribution of genetic expression of the cancer patients.

Wen-Yi Zhang et al. [8] filtered the significant features out of the 125 radio therapy (RT) data set of cancer patients which has high impact in diagnostic processes. The system was built with an intension to help the physician in order to improve the efficiency of prognostic procedures.

Abhilash Shukla et al. [9] investigated the image segmentation techniques based on the X-Ray images in detecting bone cancer after reviewing the significant features and types of bone cancer in detail. He concluded that among various image segmentation approaches K-means clustering and region growing algorithms provided best result compared to others.

Santhanalakshmi et al. [10] proposed deep learning based approach in detecting bone cancer early by examining the magnetic resonance imaging (MRI) of the patient using digital image processing and intelligent mining techniques of machine learning. To anticipate the same, the system used a elementary recurrent neural network (RNN) with long short-term memory (LSTM).

Ramik Rawal [11] implemented a prognosis solution to breast cancer identification in women's that improve their survival rate with necessitating treatment plans on time. The four machine learning algorithms—KNN, logistic regression, random forest and support vector machine (SVM)—were tested in this system's JUPYTER execution environment in order to examine the performance profile in more detail..

Sonal S. Ambalkar et al. [12] after his exhaustive survey on role of machine learning in predicting bone cancer patterns in advance over MRI reports, developed a predictive system built on k-means and fuzzy c-means clustering algorithms and implemented the same in openCV environment.

Prabhakar Avunuri et al. [13] captured the efficacy of segmentation of an image which adapted K-means and fuzzy C-means clustering in detecting bone tumours well in advance. The performance study was made with MATLAB.

Arutchelvan et al. [14] build cost effective and generic cancer prediction system incorporating data mining techniques like classification and clustering in order to predict the malignant tumours and notify with early warning signals to prevent the same.Suganeshwari et al. [15] developed a deep network for bone cancer diagnosis. The authors utilized the CNN for feature selection and SVM for classification.

Each works are about to deliver an intelligent system to diagnosis the metastases bone cancer in bit earlier which boosts the life time of patients with appropriate treatments on time.

3. Proposed Model for Bone Cancer Detection

The proposed method is designed to provide cancer sufferers with an effective treatment. To allow its functions, the application must be created in concert with the private cloud server. The following is a discussion of the key stages of the suggested system

3.1. Filtering: Data Pre-processing Technique

Noise is present in most image collections. To lessen the background noise of excessive scales, a median filter is applied to them prior to processing. The improvement of the results of later processing makes this noise reduction essential.

3.2. HCPCA: Feature Extraction Method

Using feature extraction, the constructed dataset is ready for classification with appropriate size and representation.

One variation of PCA called hierarchical clustering with principal component analysis (HCPCA) is designed to be utilized for effective feature extraction. Table 1 lists the general algorithmic steps of HCPCA [16]. Covariance is a square matrix that displays the variation among dataset components. One way to evaluate how two variables vary together is to calculate their covariance.

Table 1. Algorithm for feature extraction

[1] Provide the input information as a matrix with dimensions of m*n.
[2] Determine the matrix of covariance.
[3] Create the covariance matrix's Eigen values with Eigen matrix.
[4] Select the primary components of a feature vector to locate it.
[5] Build new dataset clusters and use K-Means clustering in the manner described below:
[6] Pick the centers of the clusters. Let "C" be their designation.
[7] Estimate the distance between two points through Euclidean geometry
[8] Every pixel should be assigned to the relevant cluster if the Euclidean distance between the cluster and each individual pixel is the shortest.
[9] After the segregation for every pixel has been finished, rebuild the new cluster center using the formula as follows: $V_i = (1/c_i)\sum_{j=i}^{c_i} x_i$ (1) where xi is the Euclidean distance of the previous cluster center, ci, and vi is the new cluster center.
[10] Repeat steps 6 through 9 for a predetermined number of times, or until a specific condition is met.

3.3. CNN: Classification Model

One kind of artificial neural network is called a CNN, or ConvNet. Input, output, and several hidden layers are the components of a CNN. One of the greatest computer vision models available today is the CNN variant known as VGG16. VGG16 is an acronym for sixteen weighted layers. The twenty-one layers in VGG16 are composed of thirteen convolutional layers, five Max Pooling layers, and three Dense layers; however, only sixteen weighted layers, or parameters that are learnable layers, are present. The most remarkable thing about VGG16 is that its main focus is on the convolution layers of a 3x3 filter with stride 1, rather than having a lot of hyper-parameters. Furthermore, the padding and maxpool layer of a 2x2 filter with stride 2 are always utilized. Figure 1 depicts the schematic depiction of the suggested model, or improvised CNN.

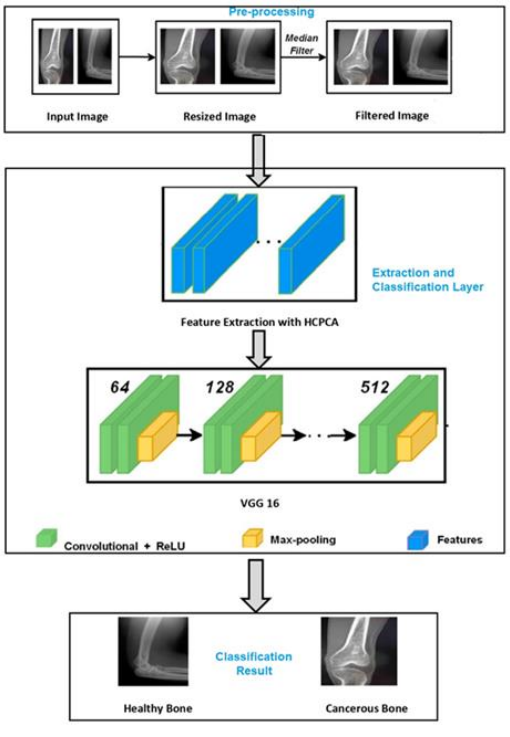

Fig. 1. Schematic diagram of proposed classification model for detecting bone cancer

4. Results and Discussion

This section includes information about the development environment on which the suggested deep learning model is employed, the dataset that was used as an input to evaluate the bone cancer, and the performance measures that were used to evaluate the suggested model.

4.1. Dataset Description

An X-ray picture dataset obtained from the Indian Institute of Engineering Science and Technology (IIEST), Shibpur repository is used as an input. A total of 100 photos in the input dataset: 50 of them show healthy bones, and the remaining 50 show cancerous bones. The basic size and homogeneity of the input photos are established by resizing them to 255 × 255 pixels.

4.2. Implementation Platform

The suggested classifier is tested using the aforementioned dataset in order to determine its overall effectiveness. The 80:20 cross-validation approach is applied here. The improvised CNN is implemented using Google Colab. The median filter is implemented using the OpenCV package. The PyTorch package was used for constructing the VGG16 model to perform feature extraction.

4.3. Evaluation Results

The effectiveness of predictive or deep learning model is rated using metrics, which are numerical measurements. These measures make it easier to compare different models or algorithms and give information on how effective the model is. The following metrics of interest, which are listed in Table 2 below, are used to evaluate how well the model employed for bone cancer detection works. The performance of suggested model (Improvised CNN) is evaluated against decision tree, KNN, logistic regression and random forest.

The Table 3 provides an illustration of the comparative performance study. The graphical representation of the same is well captured in Figure 2.

Table 2. Evaluation metrics

Metric	Formula
Accuracy (A)	$\frac{TP+FP}{TP+FP+TN+FN}$
Precision (P)	$\frac{TP}{TP+FP}$
Recall (R)	$\frac{TP}{TP+FN}$
F1-Score (F1-S)	$\frac{2*\mathrm{Pr}ecision*\mathrm{Re}call}{\mathrm{Pr}ecison+\mathrm{Re}call}$

.

Table 3. Comparative evaluation of suggested model

Models for Evaluation	Performance Metrics			
	Accuracy	Precision	Recall	F1-Score
Decision Tree	84.8	75	100	92.7
KNN	81.8	76.5	86.7	85
Logistic Regression	87.9	82.4	93.3	93.3
Random Forest	75.8	68.4	86.7	86.9
Improvised CNN	97.9	93.3	95.2	95.7

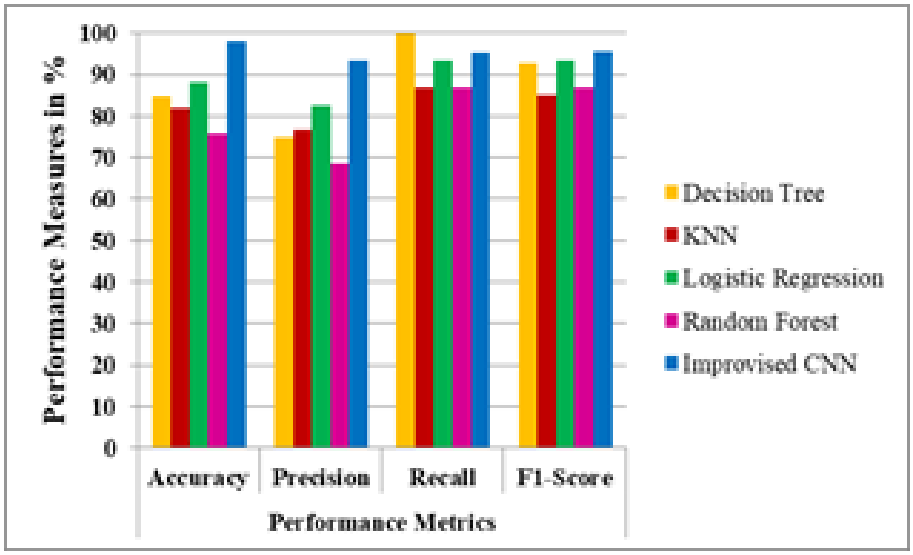

Fig. 2. Performance analysis of proposed model

5. Conclusion

Bone cancer is an uncommon kind of cancer that can outspread to various bodily parts. It is difficult and demands a great deal of specialized knowledge to do bone cancer examination by hand with adequate accuracy and dependability. The proposed classification model (VGG16-CNN Variant) is applied after the successful deployment of filtering and feature extraction by HCPCA. It gives the accuracy rate as 97.9 as compared with other learning models of evaluation.

In the future, the following approaches can be used to determine the model's viability:

- Training the suggested system on bigger datasets rather than smaller ones could improve its prediction rate
- By taking into account the different imaging modalities, an improved diagnosis system for different modalities can be developed.

Acknowledgements

No funding sources.

Author contributions

The author 1 is in charge of conceptualization, draft preparation, supervision and implementation. Author 2 & 3 extends provides implementation support and supervision. Author 4 assists in draft editing.

Conflicts of interest

The authors declare no conflicts of interest.

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