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A Hybrid Approach Using Particle Swarm Optimization and SVM for Detection of Kidney Lesions from Abdominal CT Scan Images

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ABSTRACT: The Computed Tomography (CT) technique is mostly used by radiologists for reliable detection and diagnosis of disease. In last few years so many people are suffering from kidney tumours. The kidney tumours are found in early stage, by proper treatment the patient may recover. An efficient tool is required to analyse the large images which contains heavy information for disease diagnoses and treatment. Using Segmentation unusual masses (kidney lesions) can be detected from abdominal CT scan images. The accuracy is depends on feature selection and classification technique used. There are number of models proposed in literature, but there is no unique model consistently and effectively predicting kidney lesions. Accurate kidney lesions detection is a challenge in the Medical Image Processing. In this article an intelligent hybridization approach through Particle Swarm Optimization (PSO) and Support Vector Machines (SVM) for detection of Kidney Lesions from Abdominal CT Scan Images. The SVM is used for efficient classification and PSO for efficient optimized parameters. The experimentation and simulation is done in MATLAB with Computed Tomography (CT) kidney data set on the proposed model. The performance analyses is done on the proposed model for accuracy prediction. It is observed that classification accuracy has improved in proposed model using PSO and SVM.
Keywords : Computed Tomography, kidney lesions, Segmentation, Particle Swarm Optimization, Support Vector Machines

I. INTRODUCTION

This section describes the fundamentals, terminology and, techniques used forDetection of Kidney Lesions from Abdominal CT Scan Images.

Image Processing is a set of mechanisms that are employed to enrich the quality of image. Digital image processing approaches are tremendously employed in medical filed for diagnosis of various diseases or abnormalities, which is known as Medical Image Processing. The Medical Image Processing techniques help the doctors to analyse the various abdomen related diseases. Medical image analysis reports are given by radiologists and they take help of various medical imaging modalities like CT - Computed tomography, MRI - Magnetic resonance, US - Ultrasound, other nuclear imaging approaches that involve PET- Positron Emission Tomography and SPECT - Single Photon based Emission Computed Tomography for the analysis of abdomen diseases. The imaging techniques also help radiologists in identifying the exact location, size and type/grade of the disease.

Every human being have two kidneys of fist size, bean shaped vital organs present on both side of the human spine at the lowest half close to rib cage. Both the kidneys possess at least a million functioning units, that are known as nephrons. They discard the unwanted contents like, excess fluids from the body through the urine and it also produces certain hormones that reproduce the generations of red blood cells, controls blood pressure, hold the calcium metabolism, etc. The kidneys also synchronize the level of chemicals in the blood. Most common kidney disorders are caused due to masses formed in the kidneys. The kidney masses are associated with abnormality such as Cysts, Angiomyolipoma (AML) and RCC tumors and these are also known kidney lesions. These lesions do not give any symptoms most of the times. These masses are accidentally detected during a normal CT scan.

The Images are having noise, is induced in to the CT scan images due to then CT artefacts, improper focus, motion etc. Some of the common noises in CT images are susceptible to Salt and Pepper noise, Speckle noise, Gaussian noise. Image processing approaches that canenhance the quality of the medicalimage. The resultant of the next phase of image processing is highly dependent on the image quality and thus is a significant phase in medical image processing.The various phases in medical image processing t by hat include image acquisition, pre-processing for noise removal and enhancement, segmentation for abnormality recognition and followed analysis.

Artificial Intelligence (AI) defined as how to make the computer perform things which people perform better at the movement. The AI proves man is more powerful than computer that is man having a capability take decision faster than computer. Because the man is having training knowledge (learning experience). By learning this concepts we have to write a programs in such a way that computer can also think like a human being. Neural Networks/ Computational Intelligence (CI) is used to simulate the human brain. These techniques determine the capability of a computer to learn a specific task from the available pre-existing data or from previous experimental observations. It is concentrated in the study of machine adaptive approaches that enable or facilitate sufficient intelligent behaviour in complex and changing environment. The Machine Learning Techniques are classified into supervised and unsupervised. Supervised approachesthat areextensively used for classification and regression problems. Classification deals with problems where the output is discrete and regression deals with problems where the output is continuous. Support Vector Machines, K Nearest Neighbour, Decision tress are some of the examples of supervised learning. Unsupervised learning is used when the input is required to be divided into groups and the groups are not known beforehand. K-means is an example of unsupervised learning.

Swarm Intelligence (SI) computing is an novelsoft computing mechanism that is employed to solve the optimization problems, that are designed by inspiration from the real-time biological phenomena like a swarming, flocking and herding in creatures. One such most adorable optimization techniques is Particle Swarm Optimization (PSO) that is inspired by the behavior of the swarmsi.e. flocks of birds, and in some context the human social behavior, from which the original concept of optimization hasoriginated. PSO is ainhabitants-centric optimization approach, that can carry out various functional real-time challenges.

The entire article has been arranged as following, in section II briefly gives the insight about the literature review, section III describes problem identification, objective and methodology, section IV proposes the algorithms using PSO and SVM , section V with experimentation and results.

II. LITERATURE REVIEW

The following section briefly discuss the research reviews of various diseases detection using Image processing techniques, Feature Extraction, Machine Learning and Particle Swarm Optimization techniques which are found in the literature.

The segmentation of a normal kidney, grasping the special quality of the abdominal CT image, analysing the kidney and implementing automatic segmentation of the kidney [1]. A computer-aided diagnosis approacheswas used for abdominal computed tomography (CT) scanson normal, 3-D images [17] and also be done using anatomic structure [2,5]. For Segmenting the ultrasound (US) images, texture based features that are recognized through range of Gabor kernelover the test images using a multi-sided convolution mechanism and the texture correlationsamong the regions of the segmenting curve are assessedwithin and outside segmented regions, as mentioned in the paper[4].The Dynamic Contrast Enhanced Magnetic Resonance Imaging (DCEMRI) for recognition of pivotal to survive the transplanted kidney function [6], relay on segmentation in to recognize the human kidney from the neighbouring anatomical structures via a shape-centric segmentation approach through level setsmechanisms. The Active shape models (ASMs) was discussed to evaluatethe seed point for accessing input training data, which usually results in a set of distributedpoints in coherence to the statistical elements [8]. The contour of the kidney is revealed using gradient vector flow (GVF) using concave regions [10]. An artificial neural network works on the principle of Hybrid Self Organizing Maps with image processing techniquesto detects and analyse the renal cancer tumours [14]. The various feature extraction techniques under different classifiers are discussed with performance parameters [15]. A deep learning and fuzzy logic technique was introduced for automated segmentation [19,21,22].

The mathematical morphology, neural networks, model-fitting, level-set methods, thresholding, edge-detection, and knowledge-based classification are used to extract organ regions from abdominal CT data [2]. The PSO and BSO used as repulsion factor and penalizing fitness (RP) to alleviate the stagnation problem and thatcan manage efficiently balance among exploration and exploitation [9]. The Artificial Bee Colony (ABC) algorithm that manage the outcome in concerning to the best-so-far direction and calibrate the search space of new individuals through a comparatively higher radius previously and then resultantly the scope of search space reducesas the process moves closer to converge [11]. Evolutionary Algorithms and Swarm Intelligence successful approach for optimizing parameters [13,18,24,25]. A classification method based on SVM and PSO with ABC proposed for handling various types of data for cancer classifications [20].

Sequential Minimal Optimization (SMO) is a path breaking training algorithm belonging to SVM and used to certify its validity which deals with large amount of data [7]. Feature selection mechanism in order to classify high dimensional cancer from a microarray data, that employkernel technique such as magnitude of signal to noise (SNR) ratio and refining through PSO [12] for removal of the noise.SVM and Gabor wavelet texture features was used for classification of the lesions as angiomyolipomas (AMLs) and renal cell carcinomas (RCCs) [16]. Gray Level Co-occurrence Matrix (GLCM) and shape features extraction using connected regions and variation of these feature values is used in classification of MR images brain images for malignant tumor, benign tumor and normal brain [23].

III. PROBLEM IDENTIFICATION, OBJECTIVE AND METHODOLOGY

It is observed from the literature there are numerous challenges in attaining the efficient segmentation techniques, efficient feature extraction techniques and efficient classification approaches for recognition of kidney abnormalities in Computed Tomography(CT) scan images. Over the years, many researchers have implemented various approaches to address them, still there is a technical gap for invention and improvements. Accurate assessment of kidney abnormalities is critical in Medical Science. The abdominal CT image contains various organs like liver, spleen, kidney, colon, pancreas, duodenum, inferior vena cava etc. Segmentation of kidneys from abdominal CT scan image is a challenging task as most of the organs in abdominal CT image are soft issues with no clear borders. There is number of features for an image but which features are useful for better classification for improving accuracy which depends on application. An effective way of parameter tuning required for training and testing data sets.

The main objectives of the present paper is :

1. Study Noise removal techniques, Segmentation techniques and Feature Extraction techniques to identify the chance of improving by combining the existing methods.
2. To apply Particle Swarm Optimization for tuning parameters on Polynomial Kernel Function and Radial Basis Function(RBF) of SVM Classification for detection of kidney abnormalities in Computed Tomography (CT) scan images.
3. To conduct experiments on these proposed models by using test data from medical hospitals and the Cancer Imaging Archive (TCIA) data set.

The methodology followed in this paper for detection of kidney abnormalities in Computed Tomography (CT) scan images is renal masses are obtained from kidney CT image using segmentation techniques. Feature set is acquired from renal mass medical images and used for classification. SVM based parameter optimization is proposed employesParticle Swarm Optimization to improve the overall classification performance.

IV. PROPOSED ALGORITHM USING PSO AND SVM

This section of the paper deals with algorithm used for detection of kidney abnormalities in Computed Tomography (CT) scan images using PSO for better tuning parameters and SVM for effective classification.

The proposed approach comprises of three majorSteps that are to be performed

Step 1: Compute new values of SVM parameters using PSO (Global position) from the search space based on the Global Best particle.

Step 2: Computing the classification accuracy using SVM classifier.

Step 3: Finally based on the fitness value, the SVM parameters are adjusted and this process is iterated until the best classification accuracy is obtained.

a)Classification using SVM

The SVM technique is employed to categorize the both linear and nonlinear data. The actual training set transformed into higher dimension through nonlinear mapping. The pivotal objective of SVM is to construct a Maximal Margin Hyperplane(MMH) using support vectors. The margin will be the shortest distance throughMMH to the closest training tuple of both the class. The hyper plane can be written as

$$W.X + b = 0$$

Where W is the weight vector, $W = \{w_1, w_1, \dots \dots .. w_{14}\}$ that is 14 features are extracted from First Order Statistics (FOS) and Second Order Statistics (SOS) – mean, standard deviation, RMS, variance, kurtosis, skewness, L1-Norm, smoothness, contrast, correlation, energy, homogeneity, and entropy.

The training data is a 14-tuple, $X = \{x_1, x_2, \dots \dots .. x_{14}\}$, the hyper plane is rewritten as

$$w_0 + w_1x_1 + w_2x_2 + \cdots \dots \dots \dots \dots \dots . +w_{14}x_{14} = 0$$

$$w_0 + \sum_{i=1}^{14} w_i x_i = 0$$

Any testing sample is above the hyper plane then it must satisfy equation 4.1

$$w_0 + \sum_{i=1}^{14} w_i x_i > 0 \qquad (4.1)$$

Any testing sample is below the hyper plane then it must satisfy equation 4.2

$$w_0 + \sum_{i=1}^{14} w_i x_i < 0 \qquad (4.2)$$

From equation (4.1) and (4.2)

$$\text{S1: } w_0 + \sum_{i=1}^{14} w_i x_i \geq 1 \text{ for output } y_i = +1 (4.3)$$
$$\text{S2: } w_0 + \sum_{i=1}^{14} w_i x_i \leq 1 \text{ for output } y_i = -1 (4.4)$$

From equation (4.3) and (4.4), we obtain

$$y_i(w_0 + \sum_{i=1}^{14} w_i x_i) \geq 1, \text{for } all\ i; \quad (4.5)$$

that is any training tuples fall on hyperplane S1 or S2 - these are called support vectors for classification. The training tuples may be linear or nonlinear.

Case 1:Linear Separable

There are N training tuples denoted by (x_i, y_i) for all $i = 1,2, \ldots . N$each x_i is a 14 tuple $(x_1, x_2, \ldots \ldots \ldots \ldots ., x_{14})$ attributes along with weights $(w_1, w_1, \ldots \ldots . . w_{14})$of i^{th} training tuple, and y_i € (-1, 1). The decision boundary of a linear classifier is W.X + b =0, where w and b are parameters of the model.

(i) ifx_a and x_b are two points located on the decision boundary then

$$w.x_a + b = 0 \qquad (4.6)$$
$$w.x_b + b = 0 (4.7)$$

subtract equation 4.6 from equation 4.7

$$w.(x_b - x_a) = 0$$

The dot product is zero, so the direction for w must be perpendicular to the decision boundary.

(ii) Similarly for any point x_p located above the boundary, it satisfies $w.x_p + b = k$,where k>0.

(iii)Similarly for any point x_p located below the boundary, it satisfies $w.x_p + b = k'$, wherek'>0.

For any test sample Z in the following manner

$$y = 1, if\ w.Z + b > 0$$
$$= -1, if\ w.Z + b < 0$$

In order to calculate margin we take two points one is above, and other one is below.

$$w.x_1 + b = 0 \qquad (4.8)$$
$$w.x_2 + b = 0 (4.9)$$

Subtract equation 4.8 from equation 4.9

$$w(x_1 - x_2) = 2$$
$$||w||.d = 2$$
$$d = \frac{2}{||w||}$$

The training phase of SVM involves estimating the parameters w and b of the decision boundary from training data.

$$\sum_{i=1}^{14} w_i x_i + b \geq 1, \text{for output } y_i = +1 \ (4.10)$$
$$\sum_{i=1}^{14} w_i x_i + b \leq -1, \text{for output } y_i = -1 \ (4.11)$$

From (4.10) and (4.11), we obtain

$y_i(w_0 + \sum_{i=1}^{14} w_i x_i + \text{b}) \geq 1, \text{for } all\ i = 1,2, \ldots . N;$ (4.12)

Maximizing the margins however, is equivalent to minimizing the following objective function

$$f(w) = \frac{||w||^2}{2}$$

by using Lagrange multiplier to solve the above equation 3 we get

$$L_p = ||w||^2 / 2 - \sum_{i=1}^{14} \lambda_i(y_i(w_0 + \sum_{i=1}^{14} w_i x_i + b) - 1) \qquad (4.13)$$

To minimize the value, the derivative of $L_p$with respect to w and b, and equated to zero.

$$\frac{\partial Lp}{\partial wi} = 0 \quad => w_i = \sum_{i=1}^{14} \lambda_i y_i x_i$$
$$\frac{\partial Lp}{\partial b} = 0 \quad => \sum_{i=1}^{14} \lambda_i y_i = 0$$

From the above equations find the feasible solution for w, b and λ_i . The same thing can also done by dual formulation.

Case 2: Linear Non separable case

In case 1, SVM classification decision boundaries are error free. In linear non separable case small training errors are acceptable, hence it is called Soft margin / Accept margin.

The inequality constraints to be released to accept the non-separable data. It can be achieved by introducing Slack Variable (ξ) in to the equation for optimization.

$$\sum_{i=1}^{14} w_i x_i + b \geq 1 - \xi_i, \ if\ y_i = 1 \qquad (4.14)$$
$$\sum_{i=1}^{14} w_i x_i + b \leq -1 + \xi_i, \ for\ output\ y_i = -1 \qquad (4.15)$$

Where for all i, $\xi_i > 0$.
The ξprovides an estimate of the error of the decision boundary on the training example.
The objective function is
$f(w) = ||w||^2 / 2 + C \cdot (\sum_{i=1}^{14} \xi_i)^k$, where C and k are penalty of misclassifying the training instances.
By using Lagrangian multiplier, the optimization is written as
$L_p = ||w||^2 / 2 + C.\sum_{i=1}^{14} \xi_i - \sum_{i=1}^{14} \lambda_i\{ y_i(w_0 + \sum_{i=1}^{14} w_i x_i + b) – 1) + \xi_i\} - \sum_{i=1}^{14} u_i\xi_i$ Calculate derivative of L with respect to w,b and ξ_i to zero.

$$\frac{\partial Lp}{\partial wj} = 0 \quad \Rightarrow w_j - \sum_{i=1}^{14} \lambda_i y_i x i_i = 0 \quad \Rightarrow w_j = \sum_{i=1}^{14} \lambda_i y_i x i_i$$

$$\frac{\partial Lp}{\partial b} = -\sum_{i=1}^{14} \lambda_i y_i = 0 \quad \Rightarrow \sum_{i=1}^{14} \lambda_i y_i = 0$$

$$\frac{\partial Lp}{\partial \xi i} = C - \lambda_i - u_i = 0 \quad \Rightarrow \lambda_i + u_i = C$$

b) Parameter tuning using PSO

This process takes the inputs such as SVM parameters (w, b and $\lambda_i$for linear separable case, C and k for linear non separable case, d for polynomial kernel and σ for Gaussian RBF) and generates optimized parameters for detection of Kidney Lesions from Abdominal CT Scan Images.

Step 1: Each SVM training data taken as particle with random positions P_i and velocity vectors V_i of tuning parameters, treated as Personally Best.
Step 2: weight function w = 0.5, cognitive learning factor c1= 2.0, social coefficient c2 = 2.0.
Step 3: Repeat the following steps 4 to 8 until specified number of iterations by the user or till the particles exhaust.
Step 4: evaluate the fitness function. The objective is to maximize the accuracy.
Step 5: evaluate Pbest of each particle.
Step 6: Set the best of ‘Pbests’ as global best i.eGbest.
Step 7: Update the weightening function and factors
Step 8: Update the velocity and positions of the tuning parameters
Step 9: Mark the Gbest values as the optimal solution.
Step 10: Stop

V. V.PROPOSED MODEL EXPERIMENTATION, RESULTS AND FUTURE SCOPE

This section deals with proposed methodology experimentation with dataset, results and future scope.

a) Model Experimentation

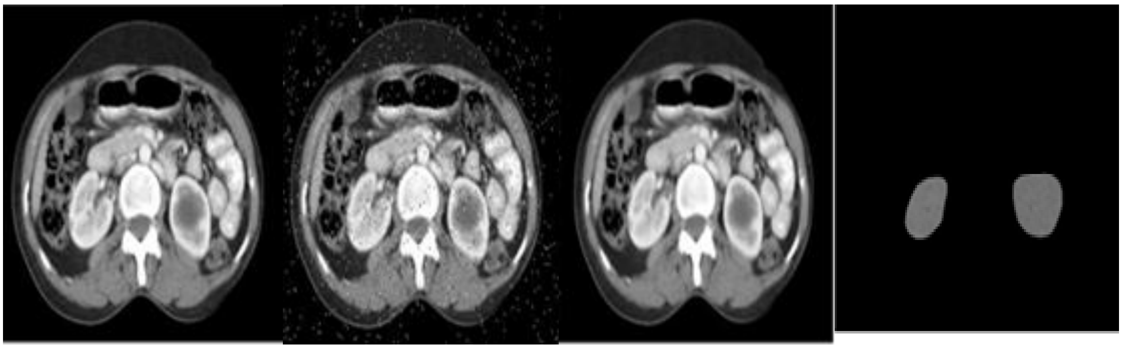
CT images Dataset containing renal mass are obtained from medical hospitals and from medical databases. The dataset includes four types Cystic, AML, RCC Tumor and Normal. The code is implemented in MATLAB for feature extraction, SVM classification and parameter tuning using PSO. The 70% of the data set is taken for training purpose and 30% data in the data set for testing is considered. First feature extraction is done from CT images, 14 parameters are supplied to SVM classifier and tested with polynomial and Gaussian radial bias kernel SVM classifier. The objective function considered for experimentation is classification accuracy, defined as

Accuracy = Correctly Classified Cases / Total Cases

b) Results and Discussions

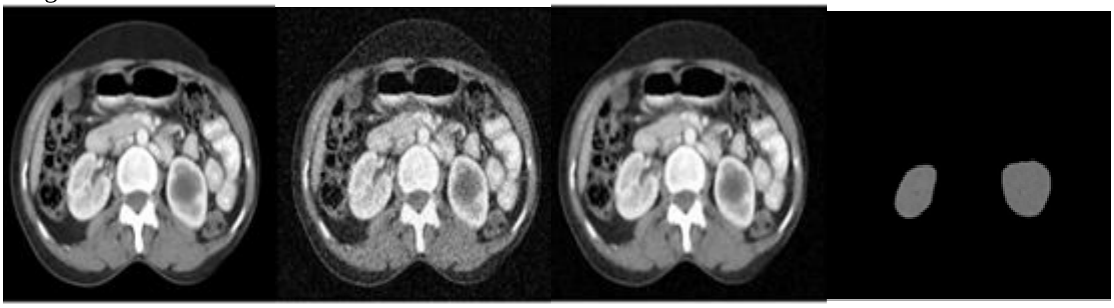
In this section SVM-PSO for polynomial kernel function and BSO-SVM for Gaussian RBF results are compared with the exiting work of Quadratic SVM and Cubic SVM from the literature and results are tabulated. The experimentation done with two kernel functions (Polynomial Kernel Function and Gaussian RBF) to determine the best upper bound. SVM-PSO with polynomial kernel function is executed to get C and d for determining classification accuracy in the first experiment. Similarly SVM-PSO with Gaussian RBF is executed to get C and σ for determining classification accuracy in the second experiment.

The following figures show Original image, the result of applying Salt and Pepper noise, Hybrid filter and Segmented Image.



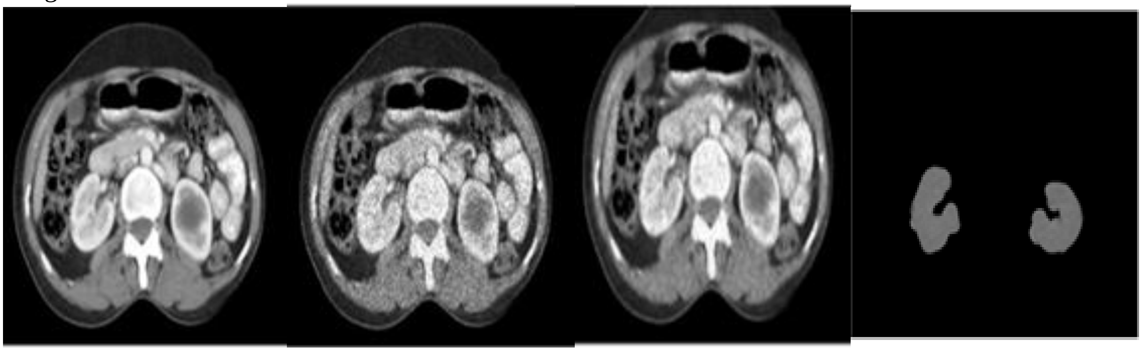
a) Original Image b)After Applying Noise c) Hybrid Filter d)Segmented Image

The following figures show Original image, the result of applying Gaussian noise, Hybrid filter and Segmented Image.



a) Original Image b)After Applying Noise c) Hybrid Filter d)Segmented Image

The following figures show Original image, the result of applying Speckle noise, Hybrid filter and Segmented Image.



a) Original Image b)After Applying Noise c) Hybrid Filter d)Segmented Image

The Classification Accuracy of SVM-PSO with polynomial kernel function and SVM-PSO with Gaussian RBF is shown in Table 5.1 and Table 5.2. The graphical representation of results are shown in Fig. 5.1 and Fig.5.2

Table 5.1 SVM-PSO with Polynomial Kernel

Classification Algorithm	**No. of Features**	**C**	**d**	**Accuracy**
Quadratic SVM	14	2	2	91.7%
Cubic SVM	14	2	3	93.8%
SVM-PSO (Proposed Model)	14	8.83	3.01	98.2%

Table 5.2 SVM-PSO with Gaussian RBF

Classification Algorithm	**No. of Features**	**C**	**σ**	**Accuracy**
Fine Gaussian SVM	14	2	0.9	68.60%
Medium Gaussian SVM	14	2	3.6	85.3%
Coarse Gaussian SVM	14	2	14	72.5%
SVM-PSO (Proposed Model)	14	8.9	3..97	96.8%

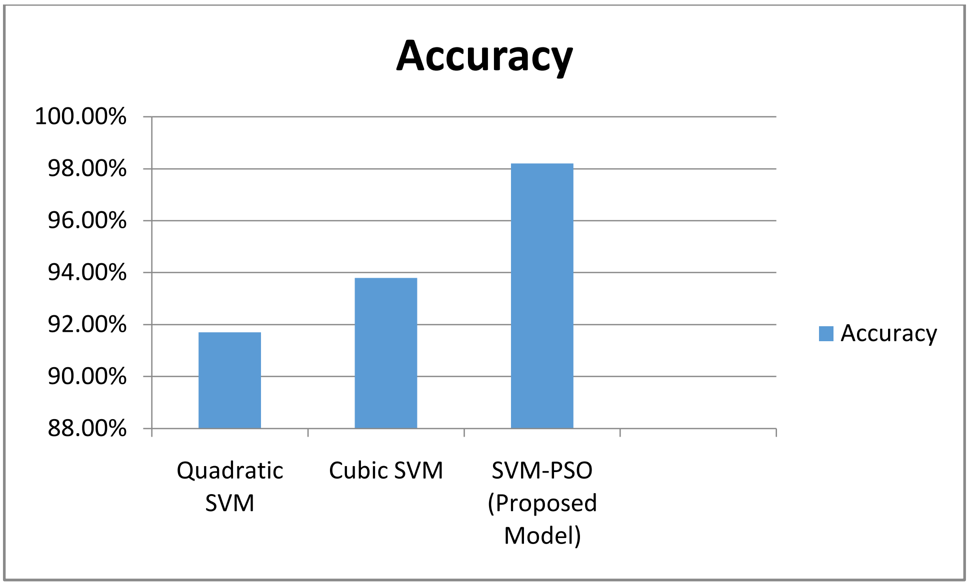


Fig.5.1 SVM-PSO with Polynomial Kernel with other models

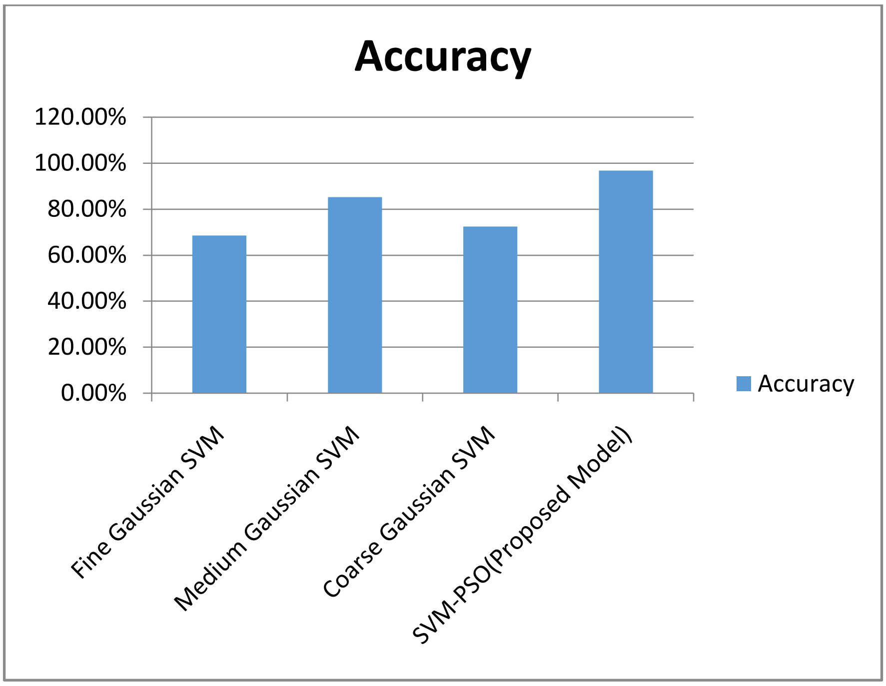


Fig.5.1 SVM-PSO with Gaussian RBF with other models

The proposed hybrid method SVM and PSO gives better results over other models based on the performance criterion Accuracy. The SVM-PSO with Polynomial Kernel resulted in accuracy of 98.2%. The SVM-PSO with Gaussian RBF resulted in accuracy of 96.8%. These Soft computing approaches to for detection of Kidney Lesions from Abdominal CT Scan Images has advantages over the other models SVM variants for better classification, and the Particle swarm Optimization can tune parameters, with ease in their implementation.

c) Future Scope

Learning a Nonlinear SVM - Construct a linear boundary using transformation space technique for learning a nonlinear data of SVM. This includes transformation of data into infinite dimensional space and reduces the computational complexity of mapping function.

VI. CONCLUSION

Accurate detection of Kidney Lesions from Abdominal CT Scan Images is very important in medical image processing for effective treatment of patients. However availability of good historical data coupled with a systematic technique can generate better results. This paper investigates to improve the accuracy by using SVM variants for better classification and PSO for effective way of tuning parameters in order to generate an optimal result. These proposed models were able to provide good accuracy capabilities as per the as per the experimental study taking parameter Accuracy.

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