Diagnosis and Classification of Thyroid Disorder using Machine Learning - A Systematic Review

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Abstract: machine learning has been used intensively and extensively by organizations around the globe. It is proving to be handy in healthcare as well. The huge quantity of data collected and produced by health and human services is complicated and needs to be refined and examined by conventional techniques. Machine learning generally involves utilization of data mining techniques and some associated learning algorithm to construct models of what is going in the reservoir of data. It provides methodology and technology to transform these heaps of data into useful information which can be used for decision making or predicting future outcomes. This information is extracted through various data mining techniques and algorithms such as association, classification, clustering, and pattern recognition and is of great use to the medical experts. The authors present the most relevant and recent research, the approaches and techniques that are followed for early diagnosis of Thyroid. The outcome of the review suggests that the accuracy of prediction can be enhanced by implementing ensemble classifier rather than a straightforward classification algorithm.

Keywords: Thyroid; Prediction; Diagnosis; Classification

1. INTRODUCTION
Diseases related to the thyroid gland are among the most common endocrine disorders affecting people worldwide. More than 40 million people in India have thyroid dysfunction, and hypothyroidism is the most common thyroid disorder. Thyroid gland, present below the voice box of the human body, is a significant organ of the endocrine system and it has a weight of 15–20 grams [1]. Thyroid gland releases two hormones namely Triiodothyronine (T3) and Thyroxine (T4) which regulate body metabolism [2]. The thyroid hormone secretion is in turn controlled by another hormone, called thyroid stimulating hormone (TSH), which is secreted from pituitary gland. An elevated TSH is usually the first abnormality to be detected. A low or high index of suspicion is important and simple blood test of T3, T4 and TSH estimation clinches the diagnosis [4]. Thyroid disorders can cause the thyroid gland to become underactive (hypothyroidism) or overactive (hyperthyroidism) [3].

Hypothyroidism disorder is much more often seen in clinical practice as compared to hyperthyroidism. The overall prevalence of it is at least 10-12 % in the general population in India as compared to 2-5% in USA and Europe. It is seen more frequently in women as compared to men (15% vs 5% respectively). Older persons have it more often as compared to younger population. Additionally, a large number of persons (6-7%) have it as a subclinical entity who may have no symptoms. A published study from Kashmir valley by Haamid Bashir and colleagues reported a very high figure of 21.5% with a predilection for females. These are the highest reports in the medical literature. Iodine deficiency used to be a common cause for hypothyroidism. Iodized salt has taken care of the dietary deficiency largely. Excessive thyroxin released from the thyroid gland kindles the heart to beat quickly and strongly, which may produce higher heart rate. This condition is known as tachycardia. The condition is detected by a doctor and may not be observed by a patient. If heart rate becomes more pronounce, then palpitations may be observed by the patient. Occasionally it can be noticed by normal individuals and may be caused by excessive exercise or drinking too much caffeine. However, if it occurs at rest and is a prolonged fast heart rate, then it may be abnormal. Palpitations may ensue in other types of heart disorders, if caused by an overactive thyroid gland, does not essentially point to a serious heart disease. In some patients, prolonged stimulation of the heart with
thyroxin may cause an incoordination of the conduction of electrical impulses within the heart and atrial fibrillation may ensue. It leads to a rapid and chaotic heart beat and pulse. The problem is often linked to weight loss even when having a good appetite, intolerance to heat, excessive sweating and tremulousness of hands and fingers. Protruding eyes (exophthalmos) may occur as well. Prolonged stimulation of heart contraction can cause some increase in blood pressure which is called systolic hypertension. The diastolic blood pressure, that is the lower of the two blood pressure readings, is not normally increased. The increased contraction of the heart with increased cardiac output causes a pulse that is easily felt at the wrist and contributes to warm sweaty hands. The diagnosis is again confirmed by assessing the thyroid hormone levels in blood which get increased (T3 and T4) and the TSH levels get low. A thyroid scan is also often done and corroborates the diagnosis and can establish inflammation as a cause.

The outline of rest of paper is structured as follows: Section 2 describes the various machine learning algorithms for classification and diagnosis of Thyroid disorder. In Section 3, the detailed survey of various works is outlined where inferences are drawn from each kind of research work. Section 4 summarizes the results of each research work in tabular form. Research outcomes achieved from survey is given in Section 5. Conclusion of this work is given in section 6.

2. MACHINE LEARNING ALGORITHMS FOR DIAGNOSIS OF THYROID

For diagnosis of Thyroid disorder various machine learning algorithms are implemented. These algorithms are able to discriminate between diabetic and non-diabetic patients. The most frequently implemented algorithms used by various researchers in their work are:

A. SUPPORT VECTOR MACHINE

A supervised learning model used for regression and classification analysis. The data points in SVM represent the dataset. In order to categorize the data, SVM builds hyperplanes which have maximum margin in multi-dimensional space. The longest distance between the nearest data points represent the margin. SVM effectively discriminates between the diabetic and non-diabetic patients.

B. ARTIFICIAL NEURAL NETWORKS

This machine learning algorithm is one of the influential learning models. Its information processing capability is like human brain. The processing speed of ANN is high because of their extremely immense parallelism. These algorithms have ability to mine patterns from complicated data and thus categorize the data accordingly. BPNN is implemented as feature selection technique in Thyroid dataset.

C. NAIVE BAYES

Naïve Bayes is an amalgamation of various classification algorithms. It is a supervised learning algorithm whose working is governed by Bayes theorem. Here it is assumed that a particular attribute does not depend on other attribute. This algorithm determines the chance of an event to occur when some another event has already occurred. The main advantage of this algorithm is that since the values are averaged the noise is reduced and more the value of probability more accurate will be the results.

D. K NEAREST NEIGHBOR

It is one of the simplest and non-parametric classification algorithms which stores all the data and groups them based on some likeness function (e.g. distance). The classification/grouping of any data point is governed by majority neighbor vote. K determines the number of neighbors to be considered for voting. Selecting the best value of K is done by examining the data. The best value of K is determined by cross-validation technique.

LITERATURE REVIEW

In order to address the issue of Thyroid and its early diagnosis, it becomes essential that previous work in the said pursuit be recorded to ease further research/progress. So in this section we review the related work regarding thyroid disorder prediction through various classification techniques. The diagnosis of any human
abnormality is mainly driven by a Computer Aided Diagnosis (CADx) framework. This framework mainly encapsulates 3 modules: Input data, Extraction of features/Selection of best features and Classification. Based on the conventional CADx framework, we have made an attempt to review previous work based on the following parameters viz: Extraction technique used, Feature selection procedures used (in some studies), Classification algorithms used and finally the accuracy of each proposed work.

M. R. Nazari Kousarrizi et al [31] specified that Hyperthyroidism can get stimulated by inflammation of thyroid gland, various medical drugs, and lack of control on secretion of thyroid hormone. Thyroid gland disorder should not be ignored or underestimated as severe hyperthyroidism (thyroid storm) and last stage of hyperthyroidism (myxedema coma), may lead to death of the patient[32, 34]. They also generalized that Diagnosis of Thyroid disorder is an essential classification problem. Sound rendering of the thyroid data is significant probe in the thyroid disease diagnosis [32, 33, 35] Several new techniques, like genetic algorithm, SVM, ANN, decision trees etc., have been applied to put patients into properly defined status, position or condition [32,33,35,36]. The researchers also proposed method that has two stages. In the primary stage, feature selection has been used as a preliminary processing step. The principle aim of feature selection is to cut the count of features used in classifying the subjects while maintaining satisfactory classification accuracy [37]. In this research sequential backward selection, Genetic Algorithm and sequential forward selection have been used as feature selection techniques. In the following stage, Support Vector Machine is utilized in classification of objects. The researchers debate that the chosen features received from the proposed technique are same as clinical experimentations utilized by medical specialists to diagnose the disease of thyroid.

Genetic algorithm (GA) is a class of optimization methods enlivened by the biological process of replication. It has been utilized to resolve several jobs including object recognition [42], target identification [43, 44], facial recognition [45, 46]. Genetic Algorithm are commonly used to generate high-quality solutions for optimization/research problems and uses series of iterations on data related to the problem domain, each one of which constitutes a candidate solution to the problem at present, specifically converted (encoded) in form of string of typifies. An arbitrarily produced set of such chains of typifies or symbols form the initial pool of solutions from which the Genetic algorithm starts its searching job. There are 3 primary genetic operators which direct this searching task namely selection, crossover & mutation. This searching process is iterative in which every string is selected, evaluated and re-combed until some terminal state is reached. Furthermore, evaluation of solution string of symbols is dependent on a fitness function which is in-turn is problem-dependent.

Support vector machines: In machine learning, support vector machines (SVMs, also support vector networks) are supervised learning models with associated learning algorithms that analyses data and recognize patterns, used for classification and regression analysis [40]. The SVM is based on statistical learning theory. The SVM solves the problem of interest indirectly, without solving the difficult problems. The support vector machine presents a partial solution to the bias variance trade-off dilemma.

Decision tree: A decision tree is a predictive modelling technique used in classification and prediction tasks [41]. Decision tree uses divide and conquer technique to split the problem search space into subsets. A decision tree is a tree where the root and each internal node is labelled with a question. The arcs emanating from each node represents each possible answer associated with question. Each leaf node represents a prediction of a solution to the problem under consideration.

Asthastha Rastogi, Monika Bhalla [38] stated An Artificial Neural Network (ANN) is a system of interlinked computing constituents namely nodes. Data is processed by the fundamental interaction amongst nodes.
Knowledge is not present in these processing nodes; rather it is represented by the weights of the associations or connections between these processing nodes. In simplest form of neural network, known as feed forward network, information or entropy moves only in one direction i.e. in forward direction, from the input processing nodes to the output processing nodes through the hidden layer or layers of nodes. Since data move in one direction, no cycles or loops in the network can exist. External or user information gets in the network via the input layer of processing nodes while the output layer of nodes produces the model situation or result. The hidden layer of nodes furnishes connections or associations necessary to discover complex patterns hidden in the data. [39]

Ozyilmaz et al. [14] in 2002 used a number of neural network methods to help diagnosis of disease of thyroid, their classification and categorization precisions are respectively 88%, 81% and 85%. In 1997, Probabilistic Potential Function Neural Network (PPFNN) classifier [15] was employed and the accuracy of 78.14% was obtained.

Pasiet al. [16], In 2004, applied 5 different methods including L.D.A, C4.5 with default learning parameters (C4.5-1), C4.5 with parameter c equal to 5 (C4.5-2), C4.5 with parameter c equal to 95 (C4.5-3) and DIMLP with tw M. R. Nazaro hidden layers and default learning parameters (DIMLP) to perform classification, and the accuracies reached 81.34%, 93.26%, 92.81%, 92.94% and 94.86% respectively.,

Polat et al. [17], In 2006, suggested applying of artificial immune recognition system (AIRS) with an accuracy of 81%. Furthermore, the author studied a hybrid method that combines AIRS with a developed Fuzzy weighted pre-processing, and obtained a classification accuracy of 85%.

Keles et al. in 2008, [18] diagnosed thyroid diseases ‘Expert System for Thyroid Disease Diagnosis’, with an accuracy of more than 95%.

Temurtas [19], in 2009 realized an accuracy of more than 93%. Using Multi-Layer Perception with Levenberg-Marquardt (LM) algorithm.

In 2011, a Generalized method for diagnosis of thyroid diseases was presented, with a classification accuracy of 91.86%, using Discriminant Analysis and Wavelet Support Vector Machine. (GDA-WSVM) [20]

In 2011, Chen [21] proposed a particle swarm optimization optimized support vector machines with fisher score (FS-PSO-SVM) CAD system for thyroid disease, and the average accuracy of 97.49% was achieved.

Arpneek Kaur et al. have used Multilayer back propagation network and self-organized map for diagnosis of thyroid disease. Weka tool has been used for the purpose. Thyroid data set is used for predicting the disease. The performance of BPN and SOM networks were found by varying the number of neurons present in the hidden layer of the network and also by the percentage of training data [22]. Yilmaz Kaya et.al. Have developed an Extreme Learning Model which is a single hidden layer feed forward neural network and is trained with gradient based learning algorithm. This extreme learning model was used in the diagnosis of thyroid disorders by performing classification and the accuracy of the classification was found to be 96.75%. 70% of the samples were used for training and 30% samples were used for testing purpose [23].

Rajkumar Nallamuth et al. have formulated several classification frameworks for diagnosis of the disease of thyroid. The classification models include C4.5, Multilayer Perceptron, and radial basis function networks. It is observed that MLP has performed well compared to other classifiers [24]. Md. Dendi Maysanjaya et al. have used MLP model using back propagation algorithm and the results of which have been compared with WEKA tool and RBF Network. It is found that MLP and RBF have given much accuracy in predicting the thyroid disease [25].

The authors Kenji Hoshi and Junko Kawakami have developed a Bayesian regularized neural network and a self-organized map to predict hyperthyroid and hypothyroid using linear discriminate analysis. For this, they
have used hormones related thyroid predicting the disease [26]. Similarly Jasdeep Singh Bhalla and Anmol Agarwal have developed hybrid neural networks for medical diagnosis using scaled conjugate gradient back-propagation and Marquardt back propagation algorithm. The input to the model is a thyroid dataset and basing on this dataset they have compared the performance of the models and found the efficiency of the prediction of ANN's in medical diagnosis [27].

Hasan Makas et al. developed seven distinct sorts of Neural Networks keeping in mind the end goal to recognize more strong and dependable systems for diagnosing the thyroid illness. They have utilized swarm optimization and ant bee colony algorithm for training and testing the networks for diagnosis of thyroid disease [28].

Chang et al. worked on several feature extraction technique including GLRLM (grey level run-length matrix), laws textures energy measures, wavelet transformation, co-occurrence matrix and Fourier features [47].

Senol et al. proposed an amalgam structure to diagnose the thyroid disease using Neural Networks and Fuzzy logic techniques [48].

Rouhani et al. made a comparative account of various Artificial Neural Network models for diagnosing the thyroid disease [49].

Isa et al. worked on a number of activation functions for Multi Layered Perceptron Neural Network to determine the most suitable function to classify the thyroid disease as Hypothyroid and Hyperthyroid [50].

Prerana, Parveen Sehgal et al. [51], proposed a precise technique for detecting the thyroid by utilizing the back propagation algorithm. Artificial Neural Network is developed using the back propagation of error to identify the preliminary thyroid prediction. ANN is trained subsequently for testing the experimentally, but not the same training sets. The training can be done in two ways as supervised learning and unsupervised learning. The experimental result is carried out in MATLAB Neural Network Toolbox Software. This provides better performance than the simple gradient descent algorithm.

**SUMMARIZATION OF PREVIOUS WORKS**

<table>
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<tr>
<th>Method/Year</th>
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<tbody>
<tr>
<td>Expert system oriented Methodology (1991)</td>
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<td>Cross validation Variable selection Regression Method (1998)</td>
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<td>Multivariate Analysis 2005</td>
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<td>Fuzzy cognitive Map (FCM) (2008)</td>
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<tr>
<td>ESTDD (Expert system thyroid disease diagnosis) (2008)</td>
<td>64</td>
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### RESEARCH OUTCOMES

Based on the detailed survey of literature in Sections III and IV, the authors summed up the following outcomes:

1. The various machine learning classifiers like Naïve Bayes, Support Vector Machines, Decision Tree achieved good results in terms of standard metrics. However, the survey suggests that the techniques like feature selection and clustering with these base classifiers further improve the achieved results.

2. The ensemble classifiers provide much better results in comparison to base classifiers trained directly. Feature selection techniques applied to ensemble further improves the results. Addition of weights to classifiers in ensemble can further improve these results.

### CONCLUSION

Prediction and diagnosis of disease plays a critical role and it is indispensable at clinical level. Lots have been done at clinical level for the effective diagnosis of thyroid; however, use of machine learning framework for the detection and diagnosis of thyroid can achieve great results. In this survey paper, the authors presented the most relevant and recent research, the approaches and techniques that are followed for early diagnosis of
Thyroid. Outcome of the review suggests that the accuracy of prediction can be enhanced by implementing ensemble classifier rather than a straightforward classification algorithm.

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