PREDICTIVE MODEL BASED ON NEURAL NETWORKS TO ASSIST THE DIAGNOSIS OF MALIGNANCY OF THYROID NODULES

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ABSTRACT

The thyroid nodule is an abnormal growth that forms lumps in the thyroid gland. Image processing opened a new era in the identification and diagnosis of nodules thyroids in which many of them are being found incidentally. It is estimated that between 4 to 10 % can be felt on physical examination, but the rest of them is determinate by ultrasound or another sophisticate image’s technique. The thyroid nodule is the most common endocrine problem in the United States, and the 10% of them contain cancer. The objective is to determine as soon as possible how bad is the nodule found, with the less invasive procedure.

A model based in a neural network is presented in this conference that minimizes the impact of an invasive method with a probability of success. A database of 1097 patients with an identified nodule is used in this study, where 703 are benign, 238 with follicular lesions and 156 was identified as carcinoma. Each data set has fifteen (15) characteristics plenty identified as input and two (2) outputs, the TIRADS (Thyroid Imaging Reporting and Data System) classification and the nodule biopsy results.

The actual Decision Support System (DSS) assists medical doctors to identify nodules at risk for being malignant; however, this platform is based on a static model with no learning capability. Every day more data from new patient can be used to increase the accuracy of the output model. The main focus of this research is to include learning capabilities to the DSS static model and converting it to a dynamic model with a learning engine and algorithm based on neural networks.

Keywords: Neural Networks, Decision Support Systems, Healthcare, Models

Scope and Topics:

- Artificial Intelligence & Expert Systems;
- Data Mining, Knowledge Discovery and Computational Intelligence;
- Health Care Systems
INTRODUCTION

The thyroid nodule is an abnormal growth that forms lumps in the thyroid gland. Image processing opened a new era in the identification and diagnosis of nodules thyroids in which many of them are being found incidentally. It is estimated that between 4 to 10 % can be felt on physical examination, but the rest of them is determinate by ultrasound or another sophisticate image’s technique. The thyroid nodule is the most common endocrine problem in the United States, and the 10% of them contain cancer. The objective is to determine as soon as possible how bad is the nodule found, with the less invasive procedure. (Horvath, Majlis et al. 2009)

The challenge of this research is to develop a framework to apply learning systems in the diagnostic of malignancy of thyroid nodules. The application of learning systems in decision support for the healthcare industry is not necessarily new, but it is certainly underdeveloped. Decision Support Systems (DSS) are based on models to predict results; these models can be static or dynamic.

Every day hospitals are getting new data from patients that can be used to improve the accuracy of the actual DSS. The identification of processes and procedures for the proposed learning framework is an interesting contribution to the industry because it will provide an ad-hoc decision specifically for the impact in the patient which can be diagnostic accuracy, avoiding in some cases a non-required intervention. It is the premise of this research that any improvement of existing static models or even dynamic models will increase the accuracy of decisions/diagnostics, and if decisions are made with greater accuracy the industry will be benefited.

THE LEARNING SYSTEMS

The point of departure of this research focuses in the systems learning capabilities. Adaptive systems include the capability to adjust their parameters and functions to improve the accuracy of their output. There are three kinds of metadata in this learning system: input data, time factor data, and output. Given a process with N input-output data pairs \( D_N = \{x(t), y(t)\}_{t=1}^N \), the main objective of adaptive modeling is to choose a model where \( \hat{y} = f(x, w), w \in \Omega \). Several techniques for approaching this equation have been developed in the field of artificial intelligence and applied in this research, which at the end delivers a model based on a neural network that improves the accuracy of the prediction compared with a static solution with no learn capability at all.(Harris, Hong et al. 2002)

Artificial intelligence is a branch of computer science that has been developed for the purpose of solving the learning problem. The most recognized approach to applying learning is the neural network. Neural networks learn by definition, through a training and/or adaptation, depending of the learning algorithm used in each case.

The Next Figure shows a basic diagram of a learning system, based on a neural network structure. There are three main components: input, learning engine, and output. This diagram is the basic approach of the framework being proposed, and will be used as a reference to create the necessary steps to identify and develop the structure and procedures of the learning system to enable construction engineers and managers to solve problems. The three components are described below.(Bastias 2006; Bastias and Molenaar 2010)

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1. \( D_N \) represents a set of pair input/output, where \( x(t) \) is the input for time \( t \) and \( y(t) \) is Output for time \( t \).

2. \( w \) is an unknown parameter vector for the model structure \( f(x(t), w) \).
Input: The data input is the most sensitive information provided to the model; its accuracy will directly impact the output. Any model is sensitive to input variables, so a deep analysis of type and quality of information is necessary to the creation of a successful model.

Learning Engine: The most complex component of any type of learning system, the learning engine, is designed to perform changes in parameters and functions, using the feedback information. In most cases, some type of artificial intelligence is used in the main engine of the system. Neural networks, fuzzy logic, or genetic algorithms are some of the most commonly seen in the content analysis for the construction industry. Modern techniques recommend the use of combinations of technologies.

Output: The output is generally an outcome, easy to measure to produce a valid feedback. This outcome is the information used to make the decision. Outcomes will vary from problem to problem, and because of the nature of learning systems, will be fixed to the ability to feed the system with reliable information.

Artificial neural networks are relatively crude electronic models based on the neural structure of the brain. The network functions like a "brain" and learns from experience. This brain modeling also promises a less technical way to develop machine solutions. One of the main drawbacks in the use of a neural network is the amount of data required to train the network, which depend on the topology and complexity given by the learning algorithm for each neuron. To produce sufficient accuracy in results with a low number of training data points, it is important to use an effective and efficient distribution of the training set. Additional challenges with neural networks are paralysis and local minima. Paralysis refers to the case when the weights unpredictably come to a standstill status and do not adjust during training. Local minima refer to the case when the weights settle on a less than optimum status (local optimum vs global optimum) (Jain and Martin 1998).

THE PROBLEM TO BE ADDRESSED

Thyroid nodular pathology is highly prevalent in the general population (estimated from 20% to 76%) and increases with age (Gharib, Papini et al. 2010). Most of the nodules in the gland are asymptomatic and only can be identified with imaging techniques.

As a result of technological advances ultrasound (US) with high frequency linear transducers (12 to 17 MHz) gives an image of extraordinary spatial resolution, which allows 1mm cyst detection and identification of solid nodules starting at 3mm. This fact parallels the radiological experience acquired in this area—allowed US to become the first line of choice to study the thyroid in face of nodular pathology (Sipos 2009).

Thyroid ultrasound is more frequently indicated in younger patients today, due to different reasons: an abnormal finding on physical examination, abnormal thyroid function tests, as assessment in relatives of thyroid cancer patients, to investigate an incidental finding (in CT, MRI, carotid Doppler, PET) or as a...
recommendation from the ENT specialist, gynecologist, nutritionist, etc. Ultrasound identifies a vast morphological range of thyroid lesions, of different sizes challenging the endocrinologist in his selection of which of the nodules will be submitted to FNAB, without overestimating its indication or excluding those that will require a FNAB.

In the management of thyroid nodular pathology an urgent need to unify criteria has arisen from the clinician’s perspective, to find common ultrasonographic parameters for cancer determination and to define benign lesions with adequate predictive value. TIRADS is a classification made by a multidisciplinary team, recently published in the JCEM (Horvath, Majlis, Rossi, Franco, Niedmann, Castro and Dominguez 2009), with the goal to solve the problem of nodule selection for FNAB.

**TIRADS CLASSIFICATION**

TIRADS –based on a series of near 2000 nodules aspirated under US and their histological analysis– proposes ultrasound criteria that allow characterization of all types of thyroid nodules: benign and non-benign (malignant), histological follicular and non-follicular pattern to be able to select those that need aspiration. The original idea was to adapt the BI-RADS concept (Breast Imaging Reporting and Data System) from the ACR (American College of Radiology) (D’Orsi, Bassett et al. 2003), to thyroid pathology.

BI-RADS classification is universally used since it was able to define and classify mammographic findings, US and MRI with variable degrees of suspicion of mammary cancer, creating a standardized system of report and score. Based on this system clinicians adopted appropriate measures for each risk group (follow-up, biopsy, surgery, etc.). Doing an analogy of BI-RADS, TIRADS defines a score for general thyroid pathology (TIRADS 1 to 6) and a score of to 2 to 6 for nodules, thus increasing chances of diagnosing cancer. In this classification system a definition was made establishing which thyroid lesions belong to the different groups (TIRADS 2, 3, 4, 5), keeping the same malignancy risk system as BI-RADS to parallel its clinical management as well (TIRADS 4 and 5: aspiration, the rest only follow-up).

TIRADS is based on the constant correlation between ultrasound image and the histological result of the FNAB. As a result of a special aspiration technique with fine needle (21, 19G) –the clot technique– enough material can be obtained for cytology and clots for histological analysis of the architecture of thyroid tissue. In this way performance of the aspirate content increases by a significant value (rate of insufficient FNAB sample <4-5%) (Domínguez, Franco et al. 1995).

**THE PROPOSED MODEL AND THE APPLICATION**

A model based in a neural network is presented in this paper that minimizes the impact of an invasive method with a probability of success. A database of 1097 patients with an identified nodule is used in this study, where 703 are benign, 238 with follicular lesions and 156 was identified as carcinoma. Each data set has fifteen (15) characteristics plenty identified as input and two (2) outputs, the TIRADS (Thyroid Imaging Reporting and Data System) classification and the nodule biopsy results.

The learning models are based on a neural network, and the most complex tasks are the construction of the topology and the selection of learning algorithms. There is a trade-off in the learning model, number of hidden layer increase the complexity but require an extra amount of data to train the network(Cimikowski and Shope 1996)
The actual decision support system assists medical doctors to identify nodules at risk for being malignant; however, this platform is based on a static model with no learning capability. Every day more data from new patients can be used to increase the accuracy of the output model. The main focus of this research is to include learning capabilities to the base static model and converting it to a dynamic model with a learning engine and algorithm based on neural networks.

Figure 2 shows the network design for the Malignancy of the thyroid nodules. Matlab™ with Neural Network toolbox® was used to develop the network. The algorithm used by the network is back propagation with purelin as the transfer function, translm as the transfer training function, and trains as the adapting function. The performance function minimized the MSE. The input layer has a vector of fifteen data points with three neurons for each output.

The neural networks must be trained in order to adjust weight and bias. The training process requires, in most cases, a considerable amount of data; however, this amount can be reduced if the data set is representative of the problem to be solved. The adaptation is that the previously-trained network is adjusted using new information through feedback. The simulation is just the evaluation of the network using data input from the patients’ information, which in total are 1097 cases.

CONCLUSIONS

This research got in the next level in the area of decision support systems in healthcare industry by applying a learning model to a problem that was constructed using experience and small amount of data with is solved with a static model. Although the healthcare discipline is very dynamic in nature, the large majority of the decision support systems are static because of the use of the new information take longer to be processed by the experts.

The data set for the learning model considered 1097 cases. In order to maintain a parallel between the original solution and this new approach, the network was trained with 700 cases. It was then adapted with 200 cases and evaluated with 197 cases. The systems output delivery the type of lesion and the Classification, when the recommendations for the TIRADS classification are followed, the ratio between the benign vs. non-benign aspirated nodules could be 1:1. This will allow savings in terms of public health costs.

Ultimately, the healthcare field will benefit from the incorporation of learning capabilities in decision support system models. The use of artificial intelligence to apply learning capabilities in its diagnostic is one appropriate way. The key is not to let model remain static and to use new information coming day-a-
day from new patients to increase the accuracy of future diagnostics, and in many cases will avoid an intervention which is thankfully by the patient.

References


