PERIODONTITIS RISK ASSESSMENT USING TWO ARTIFICIAL NEURAL NETWORK ALGORITHMS – A COMPARATIVE STUDY

Rajesh Shankarapillai, Lalit Kumar Mathur, Manju Ananthakrishnan Nair, Roy George

ABSTRACT

Background: Artificial neural networks are currently used for a variety of complex problem solving approaches where a conventional method may not be feasible. Aims & objectives: Levenberg Marquardt and Scaled Conjugate Gradient feed forward back propagation neural network algorithms were compared to assess accuracy for periodontitis risk prediction. Material and Methods: In the present study 230 subjects were assessed for major and minor periodontitis risk factors such as; age, gender, family history of periodontitis, history of periodontal surgery, diet, smoking habit, history of diabetes, history of hypertension, presence of sub-gingival restorations, bleeding on probing, debris index (OHI-S), average pocket probing depth, presence of root calculus, presence of furcation involvement and vertical bone loss. Periodontitis risk assessment was done on a grade of 1 to 5. Results: The Levenberg Marquardt algorithm performed considerably better than Scaled Conjugate Gradient algorithm by converging faster with lesser iterations and produced minimum mean square error in both training and simulation phases. Conclusion: A properly trained neural network with Levenberg Marquardt back propagation algorithm can effectively be used for periodontitis risk prediction.

Key Words: Periodontitis; Artificial neural networks; Levenberg Marquardt back propagation algorithm

Introduction

The history of neural networks started in mid twentieth century when simple neural network with limited capabilities were conceived. Neural networks may initially seem complex and computer intensive, but actually may integrate well with a clinical environment. Neural network expert systems may be trained with only clinical data and as such can be used where ‘rule based’ decision making may not always be possible; as is the case in many clinical situations. Neural networks may therefore become important decision making tools within dentistry and have applications both in improving clinical strategies and in maximizing the cost benefit of health care systems. The usability, credibility and predictability of automated systems have steadily grown over the past decade and we would like to present the logic for such a system with Artificial Intelligence.

Although it is accepted that the primary cause of periodontitis is bacterial infection of long duration, there are a number of risk factors which may increase the probability of recurrence of periodontal disease during supportive periodontal care. The risk may in such cases be caused by other factors than poor oral hygiene measures per se. Cross-sectional and longitudinal studies show conflicting results concerning age as a risk factor for periodontal disease. According to Page et al, research on the pathobiology of periodontal diseases has increased our knowledge of these diseases and proposes a transition from the repair model to the wellness model of periodontal care. A computer-based risk assessment tool which is now popularly known as Periodontal Risk Calculator (PRC) has been thus developed by them to counter these deficiencies in integration of “Wellness Model” into practical clinical practice. Properly trained back propagation networks tend to give reasonable answers when presented with inputs that they have never seen. Typically, a new input leads to an output similar to the correct output for input vectors used in training that are similar to the new input being presented. This generalization property makes it possible to train a network on a representative set of input/target pairs and get good results without training the network on all possible input/output pairs.

The Levenberg-Marquardt algorithm was designed to approach second-order training speed without having to compute the Hessian matrix; while in the conjugate gradient algorithms, a search is performed along conjugate directions, which produces generally faster convergence than steepest descent directions. The scaled conjugate gradient algorithm developed by Moller combines the model-trust region approach used in the Levenberg-Marquardt algorithm with the conjugate gradient approach and is demonstrated to be faster and better converging with reduced memory load. Two popular artificial neural networks feed forward back propagation error algorithms namely; Levenberg Marquardt and Scaled Conjugate Gradient algorithms are compared in the present study to assess accuracy for periodontitis risk prediction.

Materials and Method

The study was based on collected sample data of 230 patients from the Post Graduate Dental Wing of PAHER University, Udaipur, India. The variable array sets from 200 of the total subjects was used for training, validating and testing the neural networks during the design phase. The remaining 30 data sets were used in the constructed Simulink network models (Figure 1) for each of the employed algorithms; to simulate and assess error difference between observed risk assessment values and calculated output. The input variables for periodontitis risk assessment consisted the parameters of age,
gender, family history of periodontitis, history of periodontal surgery, diet, smoking history, pan chewing habit, history of diabetes, history of hypertension, presence of sub gingival restorations, bleeding on probing assessed by gingival index described by Loe and Silness, debris index (OHI-S), average pocket probing depth, presence of root calculus, presence of furcation involvement and the highest value for vertical bone loss confirmed by radiographs and pocket probing methods for all the four quadrants examined.

Table 1: Periodontitis risk factors with grades used as input parameters for design of neural networks

<table>
<thead>
<tr>
<th>PARAMETER</th>
<th>RANGE OF VALUES</th>
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<th>RANGE OF VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>15-60</td>
<td>History of Hypertension</td>
<td>Yes/No</td>
</tr>
<tr>
<td>Gender</td>
<td>Male/Female</td>
<td>Presence of Sub-Gingival Restorations</td>
<td>Yes/No</td>
</tr>
<tr>
<td>Family History of periodontitis</td>
<td>Yes/No</td>
<td>Gingival Index (Loe &amp; Silness)</td>
<td>0-3</td>
</tr>
<tr>
<td>History of Periodontal Surgery</td>
<td>Yes/No</td>
<td>Debris Index (OHI-S)</td>
<td>0-3</td>
</tr>
<tr>
<td>Diet</td>
<td>Vegetarian/Non-Vegetarian</td>
<td>Presence of Root Calculus</td>
<td>Yes/No</td>
</tr>
<tr>
<td>Smoking History</td>
<td>Yes/No</td>
<td>Presence of Furcation Involvement</td>
<td>Yes/No</td>
</tr>
<tr>
<td>Pan Chewing Habit</td>
<td>Yes/No</td>
<td>Average Pocket Probing Depth</td>
<td>1-10 mm</td>
</tr>
<tr>
<td>History of Diabetes</td>
<td>Yes/No</td>
<td>Vertical Bone Loss (highest value)</td>
<td>0-10 mm</td>
</tr>
</tbody>
</table>

Table 1: Periodontitis risk factors with grades used as input parameters for design of neural networks

Figure 1: Simulink Artificial Neural network Model with Detailed Core Neural Network Architecture

The input arrays trained with scaled conjugate gradient algorithm was executed for 43 seconds till 20 iterations with 6 validation checks. The best validation performance of 0.33443 was reached at epoch 14 and the gradient recorded a value of 0.23714 at the end of training phase. The combined regression for training, validation and test values was R = 0.97809.

<table>
<thead>
<tr>
<th>NEURAL NETWORK ALGORITHMS</th>
<th>LEVENBERG MARQUARDT</th>
<th>SCALED CONJUGATE GRADIENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Executed (In Seconds)</td>
<td>24</td>
<td>43</td>
</tr>
<tr>
<td>Epochs Run</td>
<td>11</td>
<td>20</td>
</tr>
<tr>
<td>Convergence Iteration</td>
<td>5</td>
<td>14</td>
</tr>
<tr>
<td>Best Performance (MSE)</td>
<td>0.13281</td>
<td>0.33443</td>
</tr>
<tr>
<td>Optimal Gradient</td>
<td>0.063334</td>
<td>0.23714</td>
</tr>
<tr>
<td>R Value Training</td>
<td>0.99997</td>
<td>0.97543</td>
</tr>
<tr>
<td>R Value Validation</td>
<td>0.94344</td>
<td>0.83761</td>
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<tr>
<td>R Value Test</td>
<td>0.96746</td>
<td>0.91896</td>
</tr>
<tr>
<td>Overall R Value</td>
<td>0.97809</td>
<td>0.944</td>
</tr>
</tbody>
</table>

Table 2: Comparisons of results obtained after the training & testing phases of levenberg marquardt algorithm and scaled conjugate gradient algorithm networks

The training phase for Levenberg Marquardt algorithm ran for 24 seconds with six validation checks in 11 iterations. The best validation performance Mean Square Error of 0.13281 was reached at epoch 5 and the training phase finished with 6 validation checks at epoch 11 after which the validation and testing parameters stopped the over fitting training phase. The regression R values for the Training Validation and test phases were computed as 0.9997, 0.94344 and 0.96746 respectively. The combined regression for training, validation and test values was R = 0.97809.
and 0.91896. The combined Regression plot showed an R value of 0.9444 at the end of scaled conjugate algorithm test phase (Figure 2). The Levenberg Marquardt algorithm training ended with a gradient value of 0.063334 with an optimum adaptive μ value of 1.00e-06 which it acquired at epoch 11; while the scaled conjugate algorithm training session closed with a gradient value 0.23714 and a mean square error value of 0.124 at the end of 20 iterations (Table 2).

The simulation errors for both the algorithms showed a similar trend (Figure 1); with the LM Simulink model displaying much less range of output error with lower and higher error output values being within the range of -0.801 to 0.496 with only 6 data sets outside the minimum limits of -0.2 to +0.2. The SCG Simulink model showed a runtime output error deviation from the target simulation output parameters ranging from -0.603 to +0.993 with 16 out of 30 simulation datasets clearly out of range of a minimum -0.2 to +0.2 error interval; confirming a prediction accuracy of less than 50% compared with LM algorithm.

Neural network algorithms in periodontitis risk assessment can be considered as an alternative to normal clinical methods used for predicting such complex problems; which lack cross examiner validity and standardization. According to the results of present study; multilayer feed forward back propagation error algorithms like Levenberg Marquardt algorithm can successfully shoulder the burden of predicting periodontal risk from a complex array of multifactorial risk factors. These may include major proven parameters like age, smoking history, diabetes diagnosis, history of periodontal surgery, average probing pocket depth, bleeding on probing, subgingival restorations, root calculus, furcation involvements and vertical bone loss; but also some minor risk factors like family history of periodontitis and hypertension, diet, gender and present oral hygiene status of the subject.

Our neural network based computational model included pan chewing habit as an additional risk factor for periodontal destruction and thus supposedly increased the sensitivity and accuracy of risk prediction for till now unseen values of input parameters from subjects for this specific geographic region. Page and his co-workers have conclusively shown the accuracy, usefulness and validity of these machine coded prediction systems.

Periodontal Risk Calculator which is the basis of PreViser Oral Health Information Suite uses mathematical algorithms to assess periodontal risk. The viability and validity of such systems have been proved substantially helpful in molding a health care strategy where age old ‘repair’ model of periodontal care can be effectively replaced by a preventive much less traumatic ‘wellness model’ emphasizing the preventive aspects of periodontal treatment strategies.
Conclusion

It can be concluded that a well-trained feed forward back propagation artificial neural network using Levenberg Marquardt algorithm can be used as a viable alternative to predict risk for future periodontal destruction in routine clinical environments where expert specialist clinical opinion may not be readily available and the proven accuracy, reproducibility and global standardization capabilities of machine learning systems using such adaptive artificial intelligence algorithms would in fact be helpful in revolutionizing periodontal treatment strategies into targeting prevention rather than cure.

Authors Affiliations

1. Rajesh Shankarapillai MDS, Professor and PhD Scholar, 2. Lalit Kumar Mathur MDS, Professor and HOD, Dept. of Periodontics, 3. Manju Ananthakrishnan Nair MDS, Professor and PhD Scholar, Dept. of Oral Surgery, Pacific Dental College, PAHER University, Udaipur, Rajasthan, India, 4. Roy George MDS, PhD(QLD), MRACDS(Endo), Discipline Head Endodontics, School of Dentistry and Oral Health, Griffith University, Australia.

References


Address for Correspondence

Dr. Rajesh Shankarapillai MDS, Professor and PhD Scholar, Department of Periodontics, Faculty of Dental Sciences Pacific Dental College, PAHER University, Udaipur, Rajasthan-3130024, India.

Email: drrrajperio@yahoo.com

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