“Design and implementation of a neural network for detecting Urinary Tract Infection in women”

Eng. J. Israel YANEZ-VARGAS  
Division de Ingenierias Campus Irapuato Salamanca  
Universidad de Guanajuato  
Salamanca, Guanajuato, 36885, Mexico  
israelsalamanca@prodigy.net.mx

Eng. J. Gabriel AGUILERA-GONZALEZ  
Division de Ingenierias Campus Irapuato Salamanca  
Universidad de Guanajuato  
Salamanca, Guanajuato, 36885, Mexico  
gabrielmsp@hotmail.com

Dr. Sergio E. LEDESMA-OROZCO  
Division de Ingenierias Campus Irapuato Salamanca  
Universidad de Guanajuato  
Salamanca, Guanajuato, 36885, Mexico  
sele3salamanca.ugto.mx

Eng. Ramon BALBOA-ARTEAGA  
Division de Ingenierias Campus Irapuato Salamanca  
Universidad de Guanajuato  
Salamanca, Guanajuato, 36885, Mexico  
balboa1984@hotmail.es

Eng. Sheila E. GONZALEZ-REYNA  
Division de Ingenierias Campus Irapuato Salamanca  
Universidad de Guanajuato  
Salamanca, Guanajuato, 36885, Mexico  
sheila.esmeralda@hotmail.com

Abstract

Urinary Tract Infections (UTI) are considered a cause of medical consultation in primary care, which often leads to start an empirical treatment until we have the results of microbiological studies; therefore it is necessary to search for a timely diagnosis especially for pregnant women because it is a high risk infection that, without being treated in a timely manner may cause abortions in pregnant women[1]. Therefore the development to create the simulation of a diagnosis of UTI is analyzed, these are tested in different training methods used in Neural Lab[2], all the results were verified using a neural network program developed in Matlab.  
Finally, a user interface was developed in Microsoft Visual Studio to classify patients based on their symptoms and test results of urine.

Keywords: Neural Networks, Urinary tract infection, Diagnosis, Classification and Risk Factors
1 Background

It is important to mention that there are some previous works that focus on the collaboration between the field of Artificial Intelligence (Neural Networks) and medicine, such as projects are: FPGA Implementation of Artificial Neural Networks: An Application on Medical Expert Systems, which aims to detect of lung disease based on symptoms and/or conditions as input factors.[3]

With the increase of urinary tract infections in women there are developed programs that seek early diagnosis using artificial intelligence like: Predictors of urinary tract infection based on artificial neural networks and genetic algorithms, by only using symptoms and the results of urinalysis.[4]

2 Introduction

Urinary tract infections are considered a source of medical consultation in primary case, as only in the medical care unit relates to the following facts: 2071 diabetic patients of which 70% had urinary tract infection, 1167 pregnant of which 67% had one or more categories of Urinary Tract Infection (UTI). In another clear example, it is estimated that in the U.S.A. the incidence of UTI's in young women is 6 to 7 million, while in Mexico according to the Ministry of Health, there are approximately 4 million women with some kind of UTI. [5]

This motives the current investigation, with the presence of factors that allow the interpretation, identification and reflex in the input-output mechanism and its standardization in the interpretation of the UTI. Therefore, the main objective of this work is to find an alternative timely diagnosis mechanism based on the use of Artificial Neural Networks (ANN), the learning process is based on the experience of Medical Doctors. An important question is: what information will be feeded to the system for the design of the ANN to detect the infection? Our approach includes the interaction, integration and identification of the following items:

- Input data to the ANN.
- The presence or absence of risk factors.
- The results of urinalysis and their corresponding isolate micro-organisms.

It will be shown, that from this information it is possible to make a decision about the diagnosis.

3 Proposed Methodology

The current research is conducted in a quantitative manner, this is because of the data-collection tool. This project is divided in several parts as shown:

1. The collection and preparation of the data (sample size, patient’s symptoms).
2. The design of the data-collection tool (survey).
3. The creation of the training set.
4. The design of the ANN.
5. The validation of the ANN.
6. The design of the user interface[6].

The data-collection tool was based on both physical and medical symptoms, and it was divided into sections for easier handling:

- The questionnaire (referring to questions during the consultation).
- The exploration (applies to the medical examination).
- The results of the urine or urinalysis (the type of bacteria).

We collected about 260 cases between the ages of 18 and 80 years old, discarding 60 cases, because they did not contain all the required information. Hence, a training set within 178 cases was created. The other 22 cases were used for validation purposes[6].

4 Development

A clinical survey was conducted, with the help of medical doctors, in a local health institution in the area of external medicine. The survey was divided into several sections including 23 symptoms and/or conditions, which are listed below:

Vaginal Infection, Recurrent Infection, Diabetes, Pregnancy, Fever (temperature), Dysuria, Polaquiuria, Vesical Tenesmus, Pruritus, Local Irritation, Hematuria, Sexual Intercourse, Other’s, Abdominal Pain, Low Back Pain, Giordano, Leukocytes, Bacteriuria, PH acid, Nitrites, Glycosuria, Microorganism[6][7]. As it was mentioned before, the samples were collected through the survey, but additional information was obtained from the electronic clinical records from the institution. Figure(1) shows the project steps:
We will now explain step by step our process:

1. The collection of surveys: it includes the collection and preparation of the electronic clinical records and urinalysis results.

2. The training set: It includes the design and creation of the training set file, which has 23 symptoms and/or conditions which are considered the system inputs, while the result of each patient’s urinalysis is the system output. Note that it was necessary to scale appropriately the inputs to the range: \(-3 \text{ to } 3\).

3. The creation of the ANN: the Neural Lab software was used for designing and training of the ANN. The implemented ANN had 23 input neurons, two hidden neurons and 1 output neuron. The characteristics of the ANN implemented are as follows:
   - A classifier ANN configuration was used \([8][9][10]\).
   - The sigmoid (logsig) function was use for neural activation \([8][9][10]\).
   - The initialization was set to Simulated Annealing + Regression at the output layer \([8][9][10]\).

Additionally, experimental results were recorded using several training methods like Conjugate Gradient, Levenberg Marquardt and Variable Metric \([8][9][10]\). Besides, we also performed a second test where we choose the best result obtained from the first test and also created a new training set and a new validation set. This was done by exchanging some cases between the training set and the validation set. It should be mentioned that the whole process was initialized again.

4. After that, we designed and implemented the software interface, which served as an intermediary between the user and the neural network. The interface design was developed using the Microsoft Visual Studio programming environment.

5. Finally, we designed the coupling between the trained ANN and the GUI (the interface was made to provide a friendly environment for the M.D.).

5 Results

5.1 First Test

In the first test, the ANN was trained using a training set with 178 cases of women in the ages from 18 to 80 years old, (the ANN used trained using the Conjugated Gradient method). In each training case the ANN was validated using the Validation Set and the confusion matrix was obtained. Also, the same experiment was performed 100 times, and in all of them we obtained different results. Similar experiments were performed using the Levenberg Marquardt and Variable Metric methods in Neural Lab and Matlab. All the data obtained is reported, the average error’s curve is shown in figure 2, where we can observe that while more iterations of the system are performed, the tendency of the curve turns linear and softer. Besides, for Neural Lab the Conjugated Gradient answer shows the best results. Our results were verified using also the Neural Network Toolbox of Matlab.

The Levenberg Marquardt method has a very good response for the classification when using the validation set, but unlike the conjugate gradient method, it starts with a good performance, but when increasing the number of iterations, the error grew instead of remaining constant or even decrease.
As shown in figure 3, the standard deviation presents better results with the Conjugated Gradient method in Neural Lab, and it has a softer behavior than the others. This shows that the classification data are closer to the average value. The responses shown in figure 3 allows us to understand and analyze which method gets a better performance, as it can be seen the Levenberg Marquardt method produces a high standard deviation, (this shows that this method does not provide good results for this specific case), while the Conjugate Gradient method produces low dispersion when increasing the number of iterations. Something worth noting is that the dispersion generated by the ANN in Matlab is increasing as the iterations progress.

5.2 Second Test

Next, the validation data exchange between the training and validation sets was performed. The behavior that gives the Conjugate Gradient method is very stable, so the development of the project is of great use, but it is necessary to realize new tests, but in this case examine just the best method “Conjugate Gradient vs Matlab”.

The results of this second test are shown in the figure 4. The two methods used in this analysis have the same behavior defined in figure 3.

As mentioned above, the method of Conjugate Gradient Neural Lab Software for their good value and response to the classification was selected. This method was compared with Matlab (using Conjugate Gradient), and the results are displayed in figure 5. The final results showed that Neural Lab obtained a classification’s percentage of 8.36% in 100 tests, while Matlab obtain a percentage of 7.409%.
The table in figure 6 shows the percentage in each case during all the iterations, each iterations contains 22 samples of the validation set, we can see that the program implemented in Matlab obtained the best error rate over the validation set, but for our practical use, the conjugate gradient method of Neural Lab has enough features for the final implementation.

In the case of the Conjugate Gradient, Neural Lab obtained a percentage of 5.745%, while Matlab generated a percentage of 4.58%, these results were obtained from the combination of the two data tests.

- **Figure 5: Average with New Data**

- **Figure 6: Table of percentage**

<table>
<thead>
<tr>
<th></th>
<th>Conjugated Gradient</th>
<th>Levenberg Marquardt</th>
<th>Variable Metric</th>
<th>Matlab</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of errors in 100 iterations with 22 samples</td>
<td>59</td>
<td>84</td>
<td>124</td>
<td>35</td>
</tr>
<tr>
<td>% Classification's errors</td>
<td>3.13</td>
<td>3.81</td>
<td>5.6</td>
<td>1.77</td>
</tr>
</tbody>
</table>

- **Figure 7: The Urinary Tract Infection Laboratory (UTILab)**

### 5.3 Implementation

For the implementation of the graphical user interface in Microsoft Visual Studio, we used a file generated in Neural Lab with extension *.lab which contains the weights of the neurons trained, this file is very easy to implement in the programming platform used for the final project design.

The neurons output is not a percentage, it is just the activation level. This activation level was used only to classify whether there was an infection or not, and depending on the symptoms and conditions in women. The figure 7 shows the final result, this is the GUI that contains all the symptoms and/or conditions, this project generates the classification of the infection depending on the variables selected by the medical doctor.

### 6 Conclusion

During all the test, the best method was the Conjugate Gradient for Neural Lab and Matlab.

The more number of iterations are performed during the training of the network, the bigger the likelihood to obtain less variation on the error probability.

The implemented software can be used as a medical assistant for the prevention and treatment of urinary tract infection in women, and it can also be used to train people who work within the health sector. Combining the symptoms and suffering from an infection and using the output of the software, the health sector worker and the patient can understand and treat better the infection.

It is necessary to note that the neuron’s output is the activation level, and is used to detect the infection by the implemented software.

For future works, we will calculate the confidence of the ANN results, thus obtain a percentage of illness or infection.

### References

[1] Infection in pregnancy women. From Secretary of Healthy
http://www.cenetec.salud.gob.mx/descargas/gpc/CatalogoMaestro/078_GPC_JVUenelemb1NA/IVU_E_R_SS.pdf
[2] Neural Lab. From Wikipedia, the free encyclopedia
http://en.wikipedia.org/wiki/Neural\Lab


[6] Juan Israel Yanez Vargas. Diseno y aplicacion de una red neuronal en la deteccion de infeccion urinaria en mujeres HGZ No. 3 IMSS Salamanca, Gto.

[7] Department of Education, Sample, Urinalysis in laboratories and medical record. HGZ No 3 IMSS SALAMANCA GTO.

