Using Neural Networks for prediction of Central Venous Pressure during Open-heart surgery

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Abstract: - In this paper, we describe a use of Neural Networks (NN) of formal neurons for predictions of Central Venous Pressure (CVP) during open-heart surgery. As input variables in the system of neural network we use primary non-invasive parameters and in the second simulation we added invasive physiological parameters of patient. CVP is a pressure in the right atrium of the heart, which is measured in very invasive way with catheter, which is placed directly into the heart. We assume that value of CVP can be predicted with only non-invasive parameters. At first we teach NN only with non-invasive input parameters captured from anesthesia machine, ECG monitor and pulse oximeter. In the second part of simulation we added invasive blood pressure (IBP) to non-invasive input parameters, which is measured in radial artery. Neural network has showed 75% correlation between central venous pressure (CVP) and non-invasive parameters. When we consider additional invasive parameter as neural network input, then success rate increase to 80%.

Key-Words: - Artificial Intelligence, Neural Network, Backpropagation, Open-Heart Surgery, CVP – Central Venous Pressure

1 Introduction

The knowledge and wisdom of human beings has been tightly connected with curiosity and nature from the early beginnings. In ancient times, 350 BC, Aristotle wrote about wisdom in his work Metaphysic [1]. He believed that research of human health is more important then research of other nonessential matters, which are design for more comfortable life. Empiric Aristotle was a strong believer in cardio centric system, where the brain had secondary role in cooling down warm blood. In our paper we placed the heart, which fascinated Aristotle in the center of our research domain.

In 2003 there were 1372 open-heart surgery planed in Slovenia. However there are a growing number of patients who are still waiting for surgery (500-600 patients). According to the American Heart Association, cardiovascular disease is the number one cause of death in the United States accounting for 950,000, or 41%, of total mortalities from all causes.

Currently there is an intensive research on how to predict invasive parameters from non-invasive parameters [8,9]. The progress in the technology, which helps us with diagnostics and therapeutic treatments, especially non-invasive methods, reduce our need for analgesic drugs and patient recovery time. With these techniques there is also a smaller chance for patient to get infection or bleed.

To predict CVP as an invasive parameter we decided to use the well-known methods of prediction methods from the Artificial Intelligence (AI) namely the Neural Networks (NN) [5]. Neural networks belong to cognitive approaches of induction methods in machine learning and is based on real time processing and distributing information, which are spread through entire network in time and space [4].

2 Problem Formulation

Central Venous Pressure is a direct measurement of the blood pressure in the right atrium of the heart and vena cava, were the blood accumulates from central vein [2]. It is a good indicator of how much volume of blood the patient is actually circulating. Veins are blood vessels where blood flows into heart direction and it presents blood storage with 60% of 6 liters of entire blood. CVP reflects not only blood volume but heart pumping condition as well. If the heart pumps blood strongly, the pressure in the right atrium reduces. Also weakening of heart increases the pressure in the right heart. CVP is acquired by threading a central venous catheter into large vein [3]. Catheter is threaded so that the tip of the catheter rests in the lower third of the superior vena cava. CVP is also measured in Intensive Care Unit (ICU). The use of central venous catheters is also

associated with adverse events that are hazardous to patients.
Heart rate is one of non-invasive parameters, which is most important in controlling physiologic variables of the patients. Fig 1 presents changing of heartbeat on one of hundred patients included in this research. Because of the special procedure, the heart must stop and this gives the surgeon bloodless field in which to work during open-heart surgery.

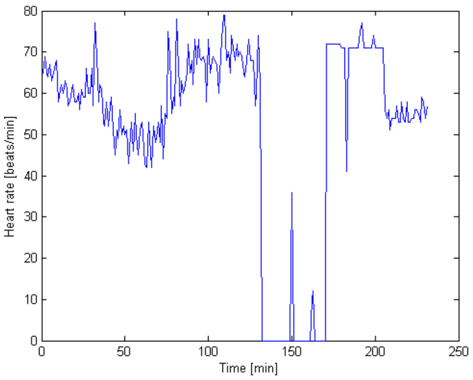

Fig 1.: Heart rate between 230 minutes long open-heart surgery

Because the heart did not act as pump anymore it was necessary to reestablish Cardiopulmonary Bypass (CPB), which causes the oxygenation of the blood, circulation and regulation of body temperature. The goal of the perfusionist, which is responsible for CPB, is to keep the patient in a normal physiologic state. Between CPB, which was finished in 170 minutes, ECG monitor has detect some noise, which was removed during the analysis of the data.
Cardiopulmonary Bypass (CPB) is a process, which is used to stop the heart from beating. The patient's blood is diverted through a heart-lung machine, which does the work of both the heart and lungs. CPB machine oxygenates the blood in the oxigenator and circulates it back through the body, leaving the heart and lungs motionless. During cardio-pulmonary bypass, we also need to be able to control the patient's temperature. In most open-heart operations we cool the patient down in order to slow and to control the way the body uses oxygen. Toward the end of cardio-pulmonary bypass, we warm the patient back up to normal temperature.

2.1 Data

During an anesthetic procedure, the physiologic state of the patient and the depth of anesthesia should be monitored. Physiologic state of patient during open-heart surgery expresses mainly in hemodinamic and respiratory parameters, which are carefully observed by anesthesiologist.

The data received during the open-heart operation are extremely important. Based on them later decisions and actions of surgical team are executed. Since human body, which is extremely sensitive system with quick and short responses, the data contains many complex relations.
Our database in open-heart surgery contains 10 attributes and the whole database consisted of 31,566 vectors, which was taken from 100 patients. The following table represents attributes, which were collected before Cardiopulmonary Bypass was performed.

Heartbeat and Saturation	Data from Anesthesia Machine		Invasive monitoring
HR	PPAUSE	ETCO2	MEANIBP
SPO2	PPEAK	INSPO2	
	PEEP	RR	CVP
	TIDVOL		

Table 1: Atribute

Captured data from Anesthesia Machine are:

- PPAUSE: inspiratory pause pressure,
- PPEAK: peak airway pressure,
- PEEP: positive end-expiratory pressure,
- ETCO2: end-tidal carbon dioxide,
- TIDVOL: tidal volume,
- RR: respiratory rate,
- INSPO2: inspiration of oxygen.

Next figure 2 represents Heart rate. As we see on figure 2, we also have heartbeats with value "0 heartbeat/minute". Such value was present in 1394 cases, which were deleted. Mean value of heart rate is 67.1 with standard deviation of 25.22 (N=24,900)

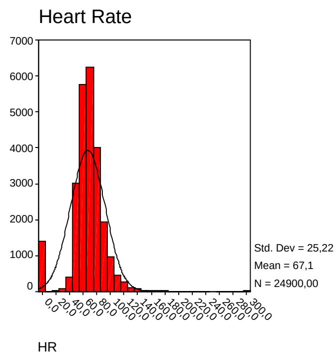

Fig 2: Heart rate during open-surgery procedure

3 Neural Networks

Neural Networks algorithms are among most popular machine learning techniques used today. They are appropriate approaches for prediction of data, which are mostly represented in a numerical format. Based on this fact the selection of NN as machine-learning tool for prediction was made in this research.

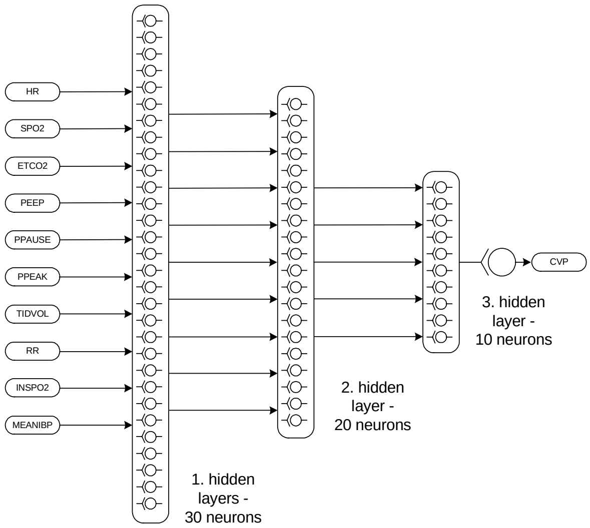

Fig 3: Three layer NN.

The main problem when designing NN is selection of the network topology. Based on the previous experiment in this case, we used the following topology: use of back propagation algorithm with feed forward organization of the network and a three-layered model of an input layer, hidden layer and output layer of formal neurons as shown in Fig 3. We train NN with tan-sigmoid transfer function in the hidden layer and a linear transfer function in the output layer.

4 Results

We performed a regression analysis between the network response (A) and the corresponding targets (T). The goal of regression analysis is to determine the values of parameters for a function that causes the function to best fit a set of data observations, as close as possible.

If a perfect fit existed between the network response and the measured data, the actual measured value of CVP would exactly equal the predicted value. Typically, however, this is not the case, and the difference between the actual value of the dependent variable and its predicted value for a particular observation is the error of the estimate which is known as the "deviation" or "residual".

The figures 4 and 6 illustrate the graphical output where the network outputs are plotted versus the targets. The best linear fit is indicated by a dashed line and the perfect fit (output equal to targets) is indicated by the solid line. We taked one fourth of the data for the validation set, one fourth for the test set and one half for the training set. The figures 5 and 7 present training, validation and test errors to check the progress of training.

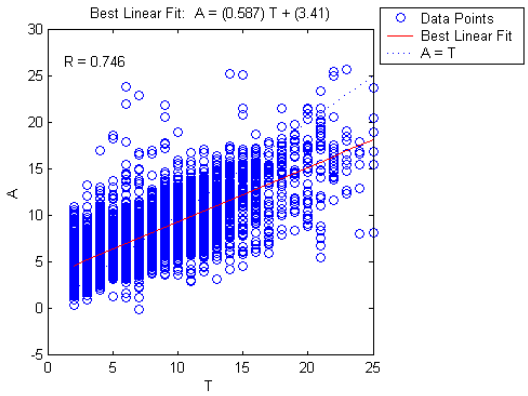

Fig 4: Regression analysis when we have only non-invasive input parameters

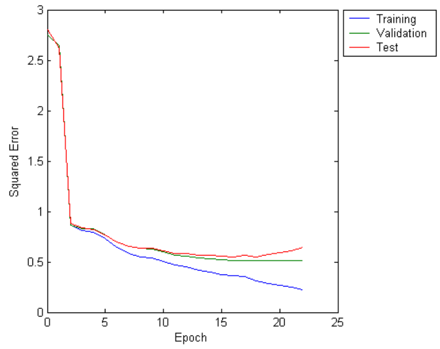

Fig 5: Training, validation and test error when we have non-invasive input parameters

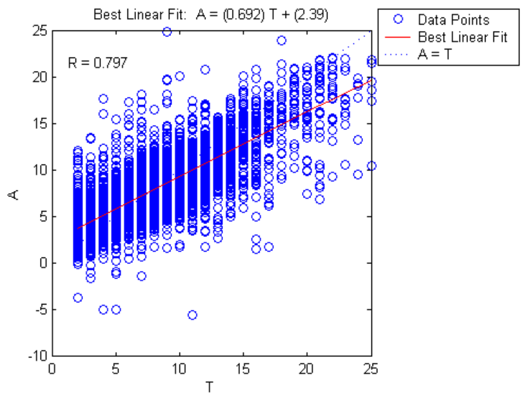

Fig 6: Regression analysis when we added one invasive input parameter (IBP).

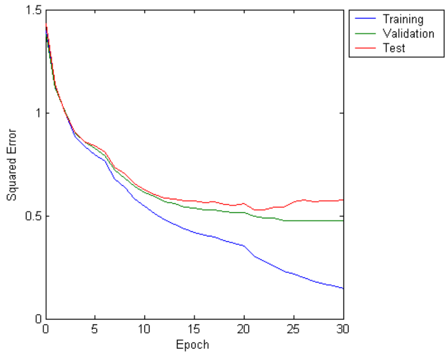

Fig 7: Training, validation and test error when we added one invasive input parameter (IBP).

4 Conclusion

In the recent years intelligent systems proofed to be a very useful and successful tool which has often been used for decision support, data mining and knowledge discovery in different fields, especially in medicine. The ability of decision support systems enabling early and accurate diagnosing is quite well known medical application but using intelligent systems and data mining is search for knowledge which should enables to replace invasive methods with non invasive ones, is a novel approach.

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