AN ARTIFICIAL NEURO DETECTOR AND ITS COGNITIVE INTERPRETATION FOR ENGINEERING SYSTEMS

D. Bayram Kara, and S. Şeker

Abstract— In this paper the definition for an artificial Neuro-Detector and its working principles are given conceptually. The methodology to be followed is simply introduced. Then some examples and suggestions to employ Neuro-detection in industry are presented through to the real world problems. The cognition run through a Neuro-Detector is discussed in terms of defining its cognitive abilities. Then the analogies between a cognitive system and an Artificial Neural Network based detector system are unfolded.

Keywords— *Detector, Auto Associative, Neural Network, Cognition*

1. Introduction

THE Neuro - Detector is a concept which is defined inspiring the human brain detection and perception ability. In order to detect an abnormal feature, human brain should first learn the normal condition. Then the abnormal condition can be identified through the comparison of the learned normal condition and noticed the abnormal one. The detected and identified abnormal condition consists of an alternative condition which should be perceived as a diverse state. To model the human brain detection and perception ability, a structure which may learn and compare is needed.

The neural networks are the best candidate for such task. Neural networks are very common mathematical tools which are used for decades to model nonlinear relationships, patterns and mappings between input output pairs. Their basic building blocks are neurons; modelled by the weighted sums of inputs, which are calculated as a function of a nonlinear activation function at output. There is an input layer which receives the intake information of the system. This information is weighted properly by the help of error propagation algorithms. The weighted inputs are summed and applied to the hidden layer whose task is the application of a nonlinear function defined for the problem. Then the output layer maps to the hidden layer. The learning ability of the network can alter due to the structure and construction, namely topology. The topology is drawn by the type of network, the sizes of input output and hidden layers, the error propagation algorithms, etc. The topology should be defined considering the nature of the problem [1-7].

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2. Basic Concepts for Neuro-Detector

The Neuro - Detectors are artificial neural network (ANN) based structures which can be used to detect a different state of the system. It can be either a faulty operation or a condition which is located out bounds of the definition space. For such application a specific type of network, named as Auto-Associative Neural Network (AANN) is required. AANN are feedforward structures which defines a mapping between input output pairs using back propagation algorithm. This type of network compresses the information, which is transferred from the inputs, at the hidden layer. And the input and output layers have the same size while the hidden layer has a smaller dimension. By this point of view, it behaves as a bottleneck for the flow of the transported information [1]. A simplified representation is shown in Figure 1.

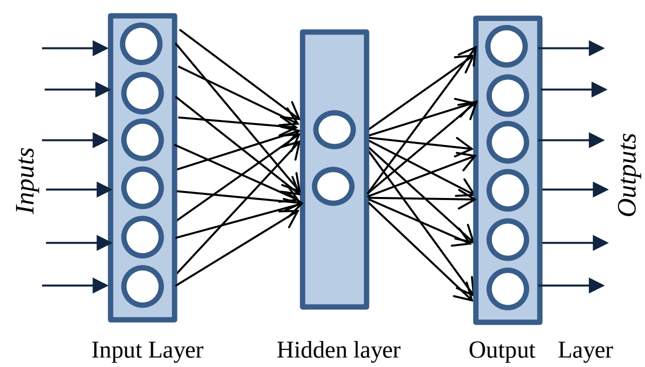

Fig.1. Simplified representation for Auto Associative Neural Network.

They can be used for the classification of complex systems, discovering patterns [2] feature extraction and dimensionality reduction in one or two dimensional systems [3, 4]. For engineering applications, it can be employed for tuning and ameliorating control, decision making, fault detection and isolation (FDI) purposes [3]. As the main FDI works, AANN can be used for sensor validation [5] or as a fault compensator for drifted sensors [6]. It can be supported by some other preprocessing operation to enhance the capability of learning such as linear prediction analysis [7] or nonlinear princaple component analysis [3].

In all of these studies, the data collected for a determined operation condition of a system is applied to an AANN and the network is trained by the data having the same trait. Speaking of the trait, the data is defined by its specific and distinctive property related to the problem. For FDI problems spectral characteristics are used commonly. The spectral representation of the system is the natural indicative for the condition of the system. In other words, the determined case's spectral representation is used to train the network. By this way, the network succeeds to recognize the defined operation. If any condition which is spectrally disparate is encountered, the network is expected to raise an error. For example, when the network is trained with any spectral representation of a healthy operation, then it will warn us with an error when a faulty operation is confronted.

3. METHODOLOGICAL BACKGROUND OF THE NEURO-DETECTOR APPLICATIONS

In order to provide a consistent Neuro - Detector application, there are some important points to be considered. For this purpose, a flow diagram given in Figure 2. First, the data should be collected representing a reference state of the system. Then the chosen form of the spectral representation of this condition are calculated. The AANN is trained by the normalized representation of this reference state. By using normalization, the characteristic of the spectral behaviour is evaluated instead of amplitude information. After a successful training procedure, the output of the network is compared with the upcoming case. If the error signal is higher than a defined threshold, which is close to the training and validation error of the network, then the error alarm can be set. Thus, the detection is accomplished using the AANN driven by the spectral properties of the collected signal. Then through the obtained error signal, the fault identification can be achieved.

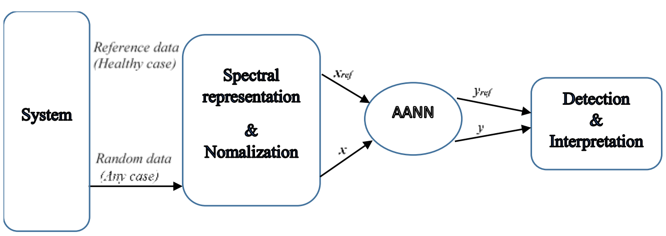

Figure 2. Flow diagram for Neuro - Detector.

4. INDUSTRIAL APPLICATIONS FOR NEURO DETECTOR

The algorithm for the detection through an AANN is suggested for industrial processes in the literature. As an example, in [8] the vibration signals of an electric motor collected for healthy operation are split to blocks and Power Spectral Densities (PSD) of the blocks are calculated. An AANN is trained through these PSDs, aiming to learn the healthy operation of the system. While the system receives PSD of a faulty operation, it is measured an error cumulated at the high frequency bands. This kind of characteristics associates with the bearing aging for electric motor.

Similarly, in [9] a Neuro - Detector is used for the identification of electric motor bearing problem. However, this time it is claimed that low frequency bands also carry hints about the bearing aging. The vibration signals collected from healthy and faulty cases of the machine are observed through the Multi Resolution Wavelet Analysis to filter specific bands of the spectrum. The AANN is trained with the low frequency band of the healthy data spectrum. The network successfully detects the bearing fault when the faulty operation is met. By the interpretation of extracted frequencies identification of specific faults are accomplished for the specific parts of the bearing.

In [10] a Neuro - Detector is designed to detect the insulation failure through the coherence analysis between current and vibration signals. The network is trained with healthy case coherence function. When the coherences of faulty case from various sensors are applied to the detector, it has successfully determined specific frequencies which associates with the insulation failure. Then as well, in [11] the coherence analysis between current and vibration signals is used to detect bearing fault. A similar procedure is adopted in this paper too.

5. CYBERNATIC APPROACH TO NEURO–DETECTOR

Since the automata and ANN are described based on finite sets, any system including the perception and learning process can be assumed as an automaton [12]. On the application, automata has the active interaction with human-machine and community. On the other hand, ANNs can be interpreted as the processing units providing the model of a complex system such any organization regarding human-machine cooperation [8].

Similar to an ANN, automata can be defined through 5 quantities as seen in (1). These are simply input, output, internal states and state functions.

$$A = (I, O, W, \Omega, \Psi) \quad (1)$$

where, I: a finite input set; O: a finite output set; W: a finite set of the internal states, Ω and Ψ are next state function and next output function respectively. While the Ω and Ψ can be defined mathematically as in (2).

$$\begin{aligned} \Omega &: W \times I \rightarrow W \\ \Psi &: W \times I \rightarrow O \end{aligned} \quad (2)$$

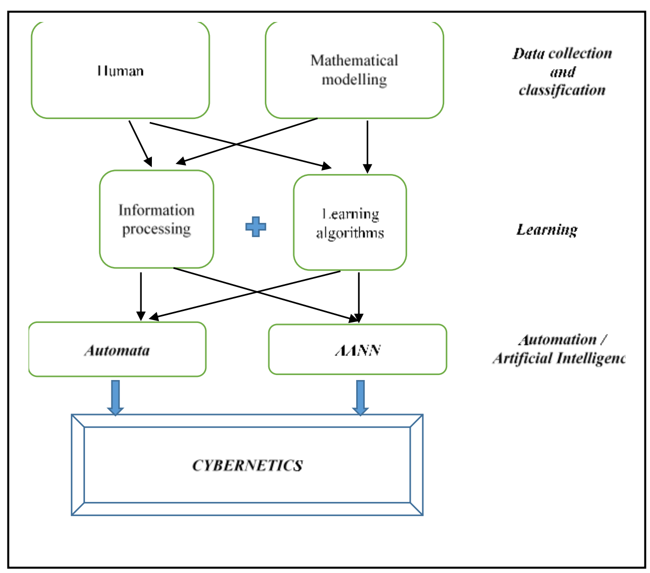

Figure 3. The information flow for a cybernetic system

For a case that input output pair number is equal, the automata and AANN resemble each other. The W associates the epochs while the Ω and Ψ represents the learning algorithm such as back propagation algorithm.

A simplified representation for the information flow of AANN and Automata is given in Figure 3. The data collection and its evaluation is executed by human effort. Then the information processing and its learning are done by the machine. The decision and built of an intelligence is succeeded by either automata or AANN. By this point of view these three stages can be considered as the interaction of Man, Machine and Cybernetic system.

6. A Cognitive approach to Neuro-Detector

A cognitive system collects information from the environment wisely by making attention and using sensing abilities to sort them to an order of importance. It learns the collected information and stores it in the memory. The capacity of learning and storing the information composes the intelligence. The integration of these skills can be interpreted as Information Processing Unit (INF-PU) of the conscious. The learned and stored information constitutes knowledge which is the precursor of decision making and taking action. Then, the actions and decisions are used for scanning of the environment again to create a new information processing operation. This flow could be called as Cognitive System Cycle (CSC).
On the other hand, artificial Neuro - Detector follows a similar flow to CSC. The sensor information is collected from the system and it is preprocessed through a trait (such as spectrum or amplitude, etc.). Then the ANN - based learning and error calculation for FDI purposes is performed. If a reasonable error is obtained, then the identification should be made. The action is developed for the identified fault.
By this point of view, as seen in Figure 4, an ANN – based Neuro - Detector can be accepted like a cognitive system in a weak sense. Pure cognitive system uses the intelligence as a function of conscious whereas the artificial one is connected with the computational intelligence.

7. Conclusions

In this study the basics for AAN - based detector are presented. A special type of network named as Auto Associative Neural Network to build a Neuro-Detector is introduced with its topological properties. The industrial applications of Neuro-Detector powered by AANN are listed. Thereafter the analogy between a cognitive system and a Neuro-Detector are highlighted.
It can be concluded that the artificial neural network shows similarities with an automata and also AAN - based systems can be accepted as the cognitive systems in a weak sense. Here, the weakness is because of the concept of consciousness. The conscious is a basic feature of a living system and it can be interpreted as a natural intelligence. However, today's technology is built upon computational intelligence rather than natural one.

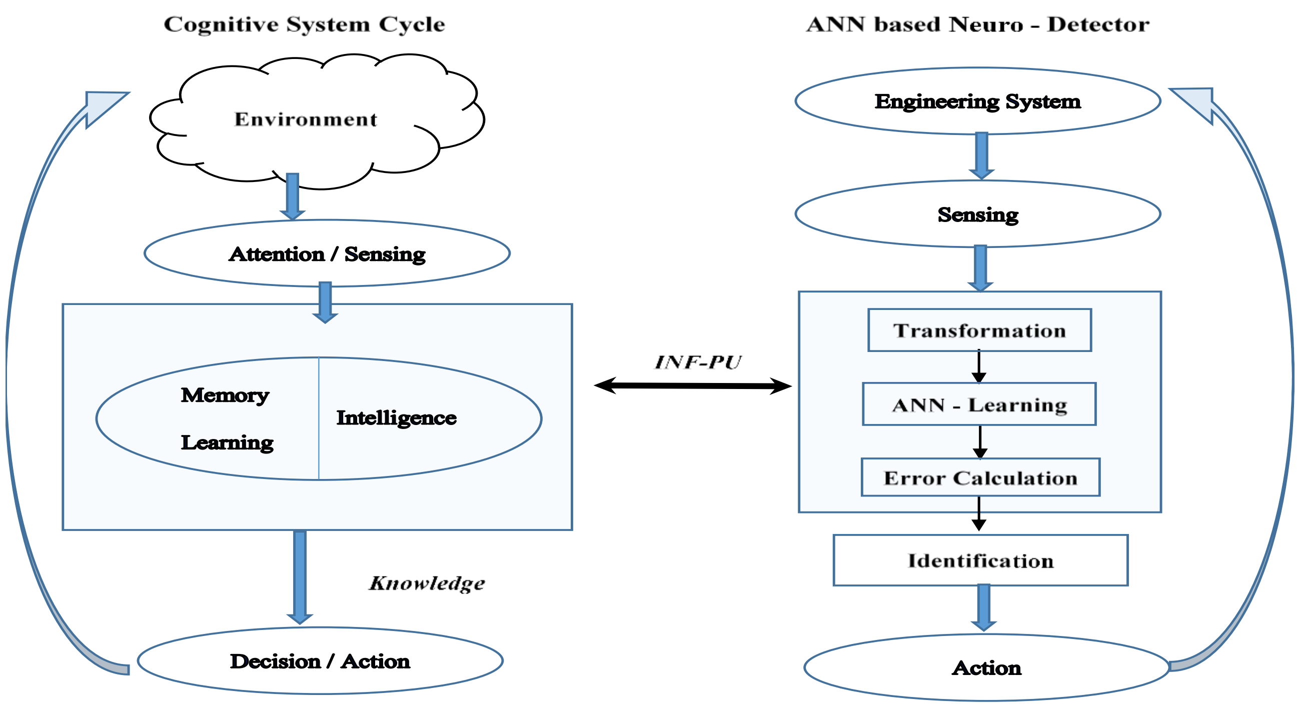

Fig.4. The analogy between a CSC and ANN based Neuro - Detector

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BIOGRAPHIES

Duygu Bayram Kara received the BSc., MSc and PhD degrees from the Electrical and Electronics Faculty of Istanbul Technical University (ITU) in 2006, 2009 and 2015, respectively. She worked as research assistant in Electrical Engineering Department at ITU between 2007-2015. She has employed by the same department as Assistant Professor since February 2016. She worked at Nuclear Engineering Department, University of Tennessee, Knoxville-USA in 2013, on in-situ condition monitoring using electrical signature analysis, as a visitor researcher. Her research areas are condition monitoring, fault detection, signal processing, soft computing electric machinery and harmonic concept. She actively provides technical consultancy service on electric motor projects for the industry.

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