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Inventor   Robert C. Higgins

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1 Attorney Docket No. 79942

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3 NEURAL NETWORK NOISE ANOMALY RECOGNITION SYSTEM AND METHOD

4

5 STATEMENT OF THE GOVERNMENT INTEREST

6 The invention described herein may be manufactured and used

7 by or for the Government of the United States of America for

8 Governmental purposes without the payment of any royalties

9 thereon or therefore.

10

11 BACKGROUND OF THE INVENTION

12 (1) Field of the Invention

13 The present invention relates generally to signal processing

14 and, more specifically, to a neural network trained to determine

15 when an input deviates from pure noise characteristics.

16 (2) Description of the Prior Art

17 Prior art signal processors attempt to detect the presence

18 of an object by filtering out background noise and applying

19 detection techniques. These detectors try to identify whether a

20 signal is embedded in background noise by comparing, for example,

21 the received waveform with a model of the signal to see if there

22 is any correlation. One disadvantage with these techniques is

23 that the transmitted signal may become distorted because the

1 amplitude, phase and frequency characteristics of the transmitted

2 signal are adversely affected as the signal propagates through

3 the medium. Hence, detection performance decreases. Such signal

4 distortion may occur in an environment where a sinusoidal pulse

5 impacts an object, traverses multiple paths and combines in an

6 unfavorable manner at the receiver array. In an underwater

7 acoustic environment, for instance, an adverse multipath effect

8 occurs when multiple reflected signals propagate through the

9 ocean after a transmitted signal has impacted an underwater

10 object like another vehicle. Multipath effects are also present

11 in most types of radio and wireless communications resulting in

12 reduced detectability.

13 Artificial neural networks (ANN) are commonly referred to as

14 neural networks or neural nets. Neural networks may typically be

15 comprised of many very simple processors, commonly referred to as

16 units or neurons, each normally having an allocated amount of

17 local memory. The units may typically be connected by

18 unidirectional communication channels or connections, which may

19 carry numeric as opposed to symbolic data. The units operate only

20 on their local data and on the inputs they receive via the

21 connections. An artificial neural network is a processing

22 device, either software or actual hardware, whose design was

23 inspired by the design and functioning of neural networks such as

1 biological nervous systems and components thereof.   Most neural

2 networks have some sort of training rule whereby the weights of

3 connections may be adjusted on the basis of presented patterns.

4 Neural networks learn from examples, just like children learn to

5 recognize dogs from examples of dogs, and exhibit some structural

6 capability for generalization.   The term "neural net" should

7 logically, but in common usage never does, also include

8 biological neural networks, whose elementary structures are far

9 more complicated than the mathematical models used for ANNs.

10   The patents discussed below describe use of a neural network

11 to act as a detector wherein an attempt is made to recognize a

12 signal pattern within noise.

13   U.S. Patent No. 5,402,520, issued March 28, 1995, to B.

14 Schnitts, discloses an apparatus for retrieving signal embedded

15 in noise and analyzing the signals.   The apparatus includes an

16 input device for receiving input signals having noise.   At least

17 one filter retrieves data signals embedded in the input signals.

18 At least one adaptive pattern recognition filter generates

19 coefficients of a polynomial expansion representing the pattern

20 of the filtered data signals.   A storage device stores the

21 coefficients generated.   It is determined when an event has

22 occurred, the event being located at any position within the data

23 signals.   An adaptive autoregressive moving average pattern

1 recognition filter generates coefficients of a polynomial

2 expansion representing an enhanced pattern of filtered data

3 signals. At least one weighting filter compares the stored

4 patterns with the enhanced pattern of data signals. The neural

5 network is trained to recognize and predict signal patterns

6 within noise as discussed above, e.g., stock price patterns,

7 rather than to recognize noise itself.

8   U.S. Patent No. 5,778,152, issued July 7, 1998, to Oki et

9 al., discloses a neural network designed to recognize a

10 particular character. The network is supplied with initial tap

11 weights for a first hidden node, which are an image of the

12 character to be recognized. The additive inverse of this set of

13 weights is used as the tap weights for a second hidden node. A

14 third node, if used is initialized with random noise. The

15 network is then trained with back propagation. The neural

16 network is trained to recognize signal patterns within noise,

17 e.g., letters, rather than to recognize noise itself.

18   The above patents do not address the value or approach of

19 recognizing noise itself. For certain types of waveforms,

20 particularly those which may or may not contain a signal embedded

21 in noise, this type of information is especially useful for

22 efficient detection. Consequently, it would be desirable to

23 provide a neural network trained to detect noise and programmed

1   to indicate if any non-noise anomalies are present. Those

2   skilled in the art will appreciate the present invention that

3   addresses the above and other needs and problems.

4

5   SUMMARY OF THE INVENTION

6   Accordingly, it is an object of the present invention to

7   provide an improved signal detector.

8   It is yet another object of the present invention to provide

9   a means for determining the presence or absence of a non-noise

10 component within noise.

11   These and other objects, features, and advantages of the

12 present invention will become apparent from the drawings, the

13 descriptions given herein, and the appended claims.

14   In accordance with the present invention, a method is

15 provided for determining the presence or absence of a non-noise

16 anomaly within noise by processing a received waveform including

17 steps such as producing a plurality of samples of the received

18 waveform and applying the plurality of samples to one or more

19 initial neural networks. Each of the one or more initial neural

20 networks may be trained to recognize noise. The initial neural

21 networks produce one or more respective outputs related to the

22 presence or absence of the non-noise anomaly. Another step

23 includes analyzing the one or more respective outputs of the one

1   or more initial neural networks to determine if the non-noise

2   anomaly is present in the received waveform. The step of

3   analyzing may further comprise applying the one or more outputs

4   to a decision making circuit for determining if a non-noise

5   anomaly is present in the received waveform.

6   The step of producing a plurality of samples may further

7   comprise dividing the received waveform into one or more windows

8   whereupon the received waveform within each of the one or more

9   windows is sampled and applied to a respective one of the one or

10   more initial neural networks. The one or more windows may be

11   incremented so as to slide relative to the received waveform with

12   each increment such that the windows are incremented until all of

13   the received waveform is sampled. Another step may include

14   storing the respective outputs from the one or more initial

15   neural networks in a database.

16   In one example, the initial neural networks are trained to

17   recognize Gaussian noise. The step of analyzing may include

18   calculating standard deviations related to the respective

19   outputs.

20   The anomaly recognition system of the present invention

21   comprises a plurality of initial neural networks, wherein each of

22   the plurality of initial neural networks may be programmed for

23   recognizing noise. The plurality of initial neural networks may

1   produce a respective plurality of outputs related to the presence

2   or absence of a non-noise anomaly. A decision making aid is

3   preferably provided for receiving and evaluating the plurality of

4   outputs from the neural networks. The decision making aid may be

5   programmed to determine if a non-noise element is present or not

6   after analyzing the plurality of outputs. The system may further

7   comprise a plurality of sampling members for providing a

8   plurality of samples of the received waveform for each of the

9   plurality of initial neural networks. In a preferred embodiment,

10   each of the plurality of sampling members is operable for

11   sampling a selected interval of the received waveform. The

12   decision making aid preferably comprises a decision module and a

13   database for storing the outputs of the initial neural networks.

14   Thus, in operation one or more initial neural networks are

15   trained to recognize the noise element. The received waveform is

16   sampled prior to filtering out the relevant noise element to

17   produce one or more samples for the one or more initial neural

18   networks. The samples are applied to the one or more initial

19   neural networks for detecting the noise element. The initial

20   neural networks produce one or more outputs responsive to the

21   noise element. A decision making aid preferably receives the one

22   or more outputs, stores and analyzes the outputs to produce a

23   decision as to the presence or absence of a noise anomaly.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the invention and many of

the attendant advantages thereto will be readily appreciated as

the same becomes better understood by reference to the following

detailed description when considered in conjunction with the

accompanying drawing, wherein the figure is a schematic block

diagram representation of a noise anomaly recognition system or

an initial or early stage of a signal processing detector in

accord with the present invention.

BRIEF DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the figure, there is shown a noise anomaly

recognition system 10 arranged for use as a neural network noise

anomaly recognition system in accord with the present invention.

One object of the invention is to recognize when a signal or non-

noise component is embedded in noise. However, recognition

system 10 is not designed to recognize the signal, which may or

may not be present in noise, but instead is designed to recognize

noise or interference. Recognition system 10 may be employed to

enhance signal detection in high noise or high interference

environments such as high interference acoustic environments as

may occur in sonar applications, in medical applications that

require a high degree of detection capabilities, and in wireless

1   communications. Recognition system 10 employs one or more neural

2   networks which can be trained to recognize particular noise

3   characteristics or other types of interference to determine when

4   the input or received signal deviates from the learned noise

5   characteristics. Additional processing may be used in

6   conjunction with recognition system 10 to identify specific

7   characteristics of any non-noise components.

8   Referring to the figure, input waveform 12 may be a waveform

9   received by anomaly recognition system 10 which typically

10 includes noise, interference, or distortion of various types,

11 e.g., reverberation, and may or may not include a signal that

12 contains intelligence or is intentionally produced for some

13 purpose. The input or received waveform 12 is then preferably

14 sampled by one or more sampling devices for initial processing by

15 artificial neural networks such as artificial neural networks 16,

16 18 and 20. In a preferred embodiment, the received waveform is

17 divided into partitions or windows as indicated at 14 and each

18 sampling member samples the portion of input or received waveform

19 12 in a particular window. The window sizes may be varied

20 depending on the application and the example shown in the figure

21 may use windows of 100, 500 and 1000 samples. If the initially

22 selected windows do not cover the entire waveform, sliding

23 windows of the data of received or input waveform 12 may be used.

1   In this case, after data sampling of the input waveform 12 is

2   performed in accordance with optimum sampling criteria, the

3   sliding windows of data are processed by neural networks, such as

4   16, 18 and 20, until all input data is processed. Preferably the

5   neural networks, such as 16, 18 and 20, will be designed to

6   accept multiple input samples (window sizes). For example, in

7   the figure the three networks 16, 18 and 20, accept 100, 500 and

8   1000 samples per window. In a preferred embodiment, each window

9   will correspond to a particular artificial neural network and the

10   artificial neural network will process each increment of the

11   corresponding sliding window to produce a number between 0 and 1.

12   The number of samples per window and the number of neural

13   networks may be changed during the training process to optimize

14   neural network performance. Furthermore, if the neural network

15   is a 3-layer backscatter model, then the number of intermediate

16   level neurons in each neural network may be varied for optimum

17   performance. Preferably, input waveform 12 is not filtered so as

18   to affect the particular type of noise for which the networks are

19   trained.

20   Neural networks, such as networks 16, 18 and 20, may be

21   trained beforehand to recognize noise, for instance white

22   Gaussian noise, and to produce a binary output of 1 when the

23   input is white Gaussian noise in this example and 0 when it

1 deviates from this. Thus, a 0 is output if there is a signal

2 present that does not depict the random characteristics of noise.

3 Although the neural networks may be trained to recognize white

4 Gaussian noise in this example, if the noise characteristics of a

5 particular application are different, then the neural networks

6 may be trained on noise with different characteristics.

7   For instance, the neural networks could recognize the

8 characteristics of a dominant interference like reverberation,

9 identify when the input characteristics are different from what

10 it has been trained to recognize, and provide an alert when this

11 happens. As an example, when an underwater array receives a

12 multipath signal embedded in noise that results from an active

13 sonar transmission, the neural network would recognize this as a

14 non-noise anomaly if no other signals were present. Also, when

15 operating as a passive sonar (i.e., listening only), anomaly

16 recognition system 10 may recognize the presence of transmissions

17 that may originate with other underwater vehicles.

18   The outputs of the neural networks, such as 16, 18 and 20

19 are preferably applied to decision aid 30 which preferably

20 comprises database 22, computational section 24 and decision

21 module 26 to produce an output of whether or not the received

22 waveform 12 is noise or includes a non-noise component as

23 indicated at 28. Database 22 may preferably be used to store the

1 output sets of the artificial neural networks as the sliding

2 windows are incremented to completely process input waveform 12.

3 Computational section 24 may be used to calculate the mean and

4 standard deviation or other statistical/descriptive criteria for

5 each of the output sets produced by the one or more artificial

6 neural networks such as the three networks 16, 18 and 20 shown in

7 the figure. The decision module 26 may preferably be used to

8 select the output set with the least volatility (smallest

9 standard deviation) and determine if the mean is closer to 1

10 (white Gaussian noise only), or to 0 (non-noise component

11 present). Decision aid 30 then preferably produces a binary

12 output of 1 or 0 to indicate the decision.

13   In summary, neural networks 16, 18 and 20 are trained to

14 identify noise, e.g., white Gaussian noise, instead of being

15 trained to recognize a signal within the noise. Since the

16 parameters that characterize a transmitted signal may change due

17 to the deleterious effects of the environment, it is believed to

18 be advantageous and in accord with the present invention to train

19 neural networks 16, 18 and 20 on noise and recognize when input

20 waveform 12 is different from noise. In accordance with the

21 present invention, this method of operation is advantageous over

22 training the neural network to recognize the specific signal

23 which may be very distorted. In a multipath environment where

1 cloud layers or ocean boundaries may cause signal distortion, the

2 approach of the present invention may be of particular value.

3 Sliding windows 14 may be applied to sections of input waveform

4 12 at the same time to produce output sets for storage in

5 database 22. Each time the windows are incremented or slide,

6 samples are taken and processed to produce a new output set.

7 Computations are made on each output set and a decision is made.

8   Alternative system structures and procedures could be used.

9 For instance, expanded or contracted window sizes that include

10 more or less data samples could be provided. A different neural

11 network model than that shown in the figure may be utilized.

12 Anomaly recognizing system 10 may be trained to recognize noise

13 only, interference only, or a combination of these or other types

14 of noise. Decision aid 30 may be constructed differently as

15 desired. For instance, database 22 may be used to store

16 processed results from the artificial networks instead of output

17 sets directly from the artificial networks. The decision

18 elements of decision aid 30 may be a digital expert system or

19 other digital computing elements.

20   Thus, numerous variations of the above method are possible,

21 some of which have already been described. Therefore, it will be

22 understood that many additional changes in the details,

23 materials, steps and arrangement of parts, which have been herein

13

1   described and illustrated in order to explain the nature of the

2   invention, may be made by those skilled in the art within the

3   principle and scope of the invention.

14

1   Attorney Docket No. 79942
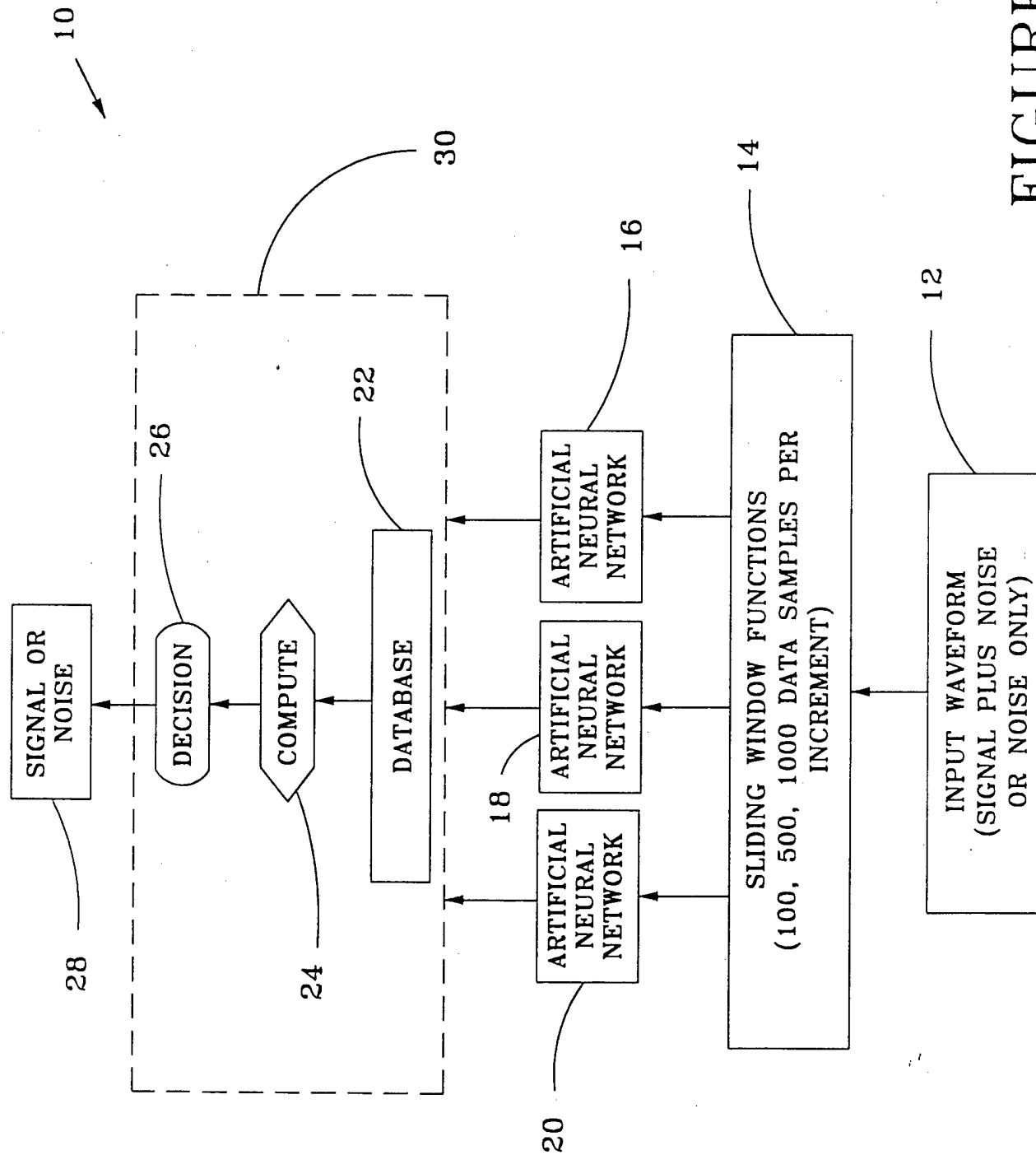
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3   <u>NEURAL NETWORK NOISE ANOMALY RECOGNITION SYSTEM AND METHOD</u>

4

5   <u>ABSTRACT OF THE DISCLOSURE</u>

6   A system and method for a neural network is disclosed that

7   is trained to recognize noise characteristics or other types of

8   interference and to determine when an input waveform deviates

9   from learned noise characteristics. A plurality of neural

10   networks is preferably provided, which each receives a plurality

11   of samples of intervals or windows of the input waveform. Each

12   of the neural networks produces an output based on whether an

13   anomaly is detected with respect to the noise, which the neural

14   network is trained to detect. The plurality of outputs of the

15   neural networks is preferably applied to a decision aid for

16   deciding whether the input waveform contains a non-noise

17   component. The decision aid may include a database, a

18   computational section and a decision module. The system and

19   method may provide a preliminary processing of the input waveform

20   and is used to recognize the particular noise rather than a non-

21   noise signal.

FIGURE