Serial Number 09/090,329

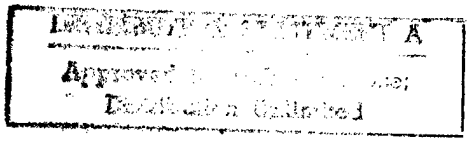
Filing Date 27 May 1998

Inventor Robert C. Higgins

NOTICE

The above identified patent application is available for licensing. Requests for information should be addressed to:

OFFICE OF NAVAL RESEARCH
DEPARTMENT OF THE NAVY
CODE OOCC
ARLINGTON VA 22217-5660



Navy Case No. 78637

NEURAL NETWORK HURRICANE TRACKER

STATEMENT OF GOVERNMENT INTEREST

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

The present invention relates to a method for predicting the path of a hurricane and to a system for implementing the method.

(2) Description of the Prior Art

Neural networks are well known in the prior art. U.S. Patent Nos. 5,461,699 to Arbabi et al. and 5,563,983 to Nozaki et al. illustrate some of the prior art layered neural network systems. Arbabi et al. describe the use of such a neural network in a forecasting system.

Attempts have been made to develop systems using neural network technology for predicting weather related and natural phenomena. U.S. Patent No. 5,140,523 to Frankel et al. describes a neural network for predicting lightning. U.S. Patent No. 5,490,062 to Leach et al. describes a neural network earthquake profile predictor. There have been no known efforts to date to

use neural network technology in a method or a system for predicting the path of a hurricane.

Currently, satellites are used to obtain the data needed to track a hurricane. Data generated by the satellites is used to create physical models for forecasting purposes. Statistically based techniques are used to generate the forecasts. Several problems exists with this approach. First, initial information provided by the remote sensors on the satellites is sparse, making the prediction process more formidable in the early stages of the hurricane's formation and movement. Second, the measured parameters like wind speed and location have a great deal of uncertainty. Third, forecasting has a subjective component making the requirement for skill and experience a necessity.

The hurricane path prediction method and system of the present invention overcome these shortcomings in the existing hurricane prediction systems.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a neural network based system for predicting the path of a hurricane.

It is a further object of the present invention to provide a system as above which has an inherent capability to incorporate historical data in the prediction process.

It is yet a further object of the present invention to provide an improved method for predicting the path of a hurricane.

The foregoing objects are realized by the system and method of the present invention.

In accordance with the present invention, a method for predicting the path of a hurricane broadly comprises providing a neural network having a plurality of layers including an input layer, an output layer, and an intermediate or hidden layer between said input and output layers, inputting real-time information about a hurricane being tracked into the input layer, and outputting an output signal from the output layer representative of a predicted path of the hurricane being tracked.

The system for implementing the above method broadly comprises means for gathering real-time data about said hurricane and a neural network having an input layer for receiving the real-time data about the hurricane, an intermediate or hidden layer for processing the data, and an output layer for generating a signal representative of a predicted path for the hurricane.

Other details of the method and system of the present invention, as well as other objects and advantages attendant thereto, are set forth in the following detailed description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of the hurricane tracking system of the present invention;

FIGS. 2(a)-2(f) illustrate the input data supplied to the neural network of FIG. 3;

FIG. 3 is a schematic representation of a neural network which can be used in the system of FIG. 1; and

FIG. 4 illustrates a prediction of the hurricane path generated by the system of FIG. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Referring now to the drawings, FIG. 1 illustrates a hurricane tracking system 10 in accordance with the present invention. As shown therein, the system 10 includes a module 12 containing information or data about the hurricane being tracked, a neural network 14, a device 16 for displaying the predicted track of the hurricane generated by the neural network 14 and a database 18 for storing information about the hurricane being tracked and for storing historical data about previous hurricanes for use in training the neural network.

The module 12 receives and processes real-time information about the hurricane being tracked from a plurality of remote sensors (not shown). The sensors may be linked to the module 12 in any desired manner known in the art. For example, the sensors may comprise sensors onboard an aircraft flying through the hurricane or sensors at land- or ocean-based stations, which

sensors provide information or data about the hurricane. The data may include the location of the hurricane center in latitude and longitude (degrees), the pressure in the hurricane center in inches of pressure, the velocity of the hurricane center in knots or kilometers/hour, hurricane wind direction (degrees), and the maximum wind speed of the hurricane in miles/hour. The module 12 is preferably formed by a portion of a preprogrammed computer and preferably includes computational devices for determining or computing certain input parameters such as changes in the velocity of the hurricane center and average wind speed of the hurricane and for scaling data prior to input to neural network 14 and means for storing the data. The computational devices (not shown) may comprise any suitable devices known in the art. For example, they can be a portion of the computer programmed to carry out certain computational functions. The data supplied from the module 12 to the neural network 14 is termed real-time data since it is based on information received from the remote sensors. The data supplied by the module 12 to the neural network 14 is preferably updated at predetermined intervals, for example every two hours. The data may also be fed from the module 12 to the database 18 for long-term storage.

FIGS. 2(a)-2(f) illustrate some of the information which may be supplied by the module 12 to the neural network 14 and used to generate a prediction of the hurricane track. FIG. 2(a) is information about the location history of the hurricane center in terms of longitude and latitude. FIG. 2(b) is information about

the velocity of the hurricane in knots as a function of time. FIG. 2(c) is information about the change in the velocity of the hurricane in knots per hour as a function of time. FIG. 2(d) is information about wind speed in miles per hour as a function of time. FIG. 2(e) is information about the pressure in the center of the hurricane in inches as a function of time. FIG. 2(f) is information about the wind direction in degrees. The data supplied to the neural network 14 may actually be estimates of the aforementioned data measurements.

Referring now to FIG. 3, the neural network 14 comprises an input layer 20, an intermediate or hidden layer 22 and an output layer 24. The input layer 20 comprises a plurality of neurons 26 with at least one input neuron for each input data set. For example, where the input data to be supplied to the neural network is the information shown in FIGS. 2(a) - 2(f), the input layer 20 would have six or more neurons 26 depending on the number of components required to represent each data set. The hidden layer 22 also includes a plurality of neurons 28. The number of neurons 28 in the hidden layer preferably equal the number of neurons 26 in the input layer 20. In other words, where the input layer 20 has six neurons 26, the hidden layer 22 will have six neurons 28. Each neuron 28 is connected to each of the neurons 26. The output layer 24 is preferably formed by two output neurons 30 with each output neuron 30 being connected to each of the neurons 28. The information from the two output neurons 30 represents a value of a predicted latitude and

longitude several hours in advance of the hurricane. The various neurons in the layers 20, 22 and 24 are linked by weighted values or links. The number of input, output, and hidden layer neurons can be varied to improve the forecasting capability of the neural network.

The neural network 14 may be implemented in any manner known in the art. For example, the neural network 14 may be implemented by a computer (not shown) which is preprogrammed with software for creating the desired neural network, namely one which can be trained using a well known back propagation technique and which can also be used in a well known feed forward manner. The software may process the input data to reach a prediction as to the track of the hurricane in any desired manner. The architecture of the software does not form part of the present invention.

As previously discussed, the output layer 30 is used to periodically generate an output signal 32 representative of a predicted latitude and longitude several hours in advance of the hurricane. The output signal 32 falls in a defined numerical range which represents latitude and longitude values. For example, neural network outputs between 0 and 1 may represent latitude or longitude values between 0 and 180 degrees.

The system 10 preferably includes a device 16 for displaying the predicted track of the hurricane generated by the output layer 30 of the neural network 14. The display device 16 can be any suitable display device known in the art such as a video

monitor and/or a printer. If desired, the display device 16 may be omitted.

Finally, the system 10 includes database 18. The database 18 may be used for a variety of purposes. For example, it may be used to store historical data which is used to train the neural network 14. Additionally, it may be used to store the real-time information being inputted into the neural network 14 as well as the hurricane path predictions generated by the neural network 14. The stored hurricane track predictions may be used to later train or retrain the neural network 14. The database 18 may be a portion of the memory of the computer used to implement the neural network 14. Alternatively, the data base 18 may comprise a separate storage device such as a tape storage device.

Prior to use as a predictor of the track of a hurricane, the neural network 14 must be trained to determine the neural network parameters that provide the "best" tracks. Any back propagation technique known in the art may be used to train the computer. A back propagation technique is employed because the topology of the neural network lends itself to supervised learning.

The data used to train the neural network comes from the information about past hurricanes stored in the database 18. For a first iteration, information from a previous hurricane is inputted into the input layer 20 of the neural network 14. The information which is inputted into the neural network 14 comprises historical information about the location of the center of the hurricane, the velocity of the hurricane center, the

change in velocity in the hurricane center, the average wind speed of the hurricane, the pressure in the center of the hurricane, and the direction of the hurricane winds, all at a point in time. Arbitrary weights are assigned to the links between the various layers and a predicted track for the hurricane is computed by the neural network. The error between the predicted track for the hurricane and the actual, or known historical track of the hurricane is then computed or calculated. The internal weights in the neural network are then adjusted to reduce the error. The process is repeated using input data available for other times during the course of the hurricane until the error reaches a predetermined acceptable level. Then, information about a second hurricane track is inputted into the neural network and the process is repeated. The training may be repeated for as many iterations as desired. For example, information from 25 to 100 different hurricanes may be inputted into the neural network 14 to train it. Training continues until the neural network is capable of producing a statistically accurate output for previously unseen input data. At that point, the neural network 14 is deemed to be trained and the knowledge is stored in the internal weights or links. Typically, the weight information is stored for future use.

In a preferred embodiment of the present invention, the information inputted into the neural network 14 to train it is about hurricanes in a specific geographic region with a history

of hurricane activity, thereby constraining the training data set to that particular area.

After training is completed, the system 10 is used to predict the track of a hurricane using the aforementioned input data from the module 12 and the stored weight information. The input data is preferably updated periodically, such as every two hours. The neural network 14 is used to generate a predicted track for the hurricane at specific intervals, such as every two hours.

Statistical methods for estimation do not typically incorporate historical data into the estimation process. One of the advantages to the system of the present invention is that the neural network 14 can be trained with a subset of historical data. This subset can include as much data as necessary to produce a statistically "good" track with a predefined degree of accuracy. This approach captures the skill and experience missing in statistical techniques used today.

While specific input parameters to the neural network 14 have been mentioned hereinbefore, it should be recognized that other or additional input parameters may be used. For example, other parameters such as amount of rainfall, storm surge conditions, or wave height measurements may be used.

If desired, the output positional parameters produced by the neural network 14 may be described in another coordinate system like polar coordinates instead of longitude and latitude.

It is apparent that there has been provided in accordance with the invention described herein a neural network hurricane tracker which fully satisfies the means, objects and advantages set forth hereinbefore. While the invention has been described in connection with specific embodiments thereof, it should be apparent that those skilled in the art may arrive at other variations, alternatives, and modifications. It is intended to embrace such variations, alternatives and modifications.

Navy Case No. 78637

NEURAL NETWORK HURRICANE TRACKER

ABSTRACT OF THE DISCLOSURE

The present invention relates to a method and a system for predicting the path of a hurricane. The system includes sensors for gathering real-time data about the hurricane and supplying the data to a trained neural network for yielding a predicted path for the hurricane. The system further includes a device for displaying the predicted path of the hurricane. A method for using and training the neural network in the system is described. In the method, the neural network is trained using information about hurricanes in a specific geographical area maintained in a database. The training involves inputting a plurality of parameters about at least one historical hurricane track and producing an output signal representative of a predicted hurricane path. An error is calculated between the output signal and the actual track and the internal weights of the neural network are adjusted to reduce the error.

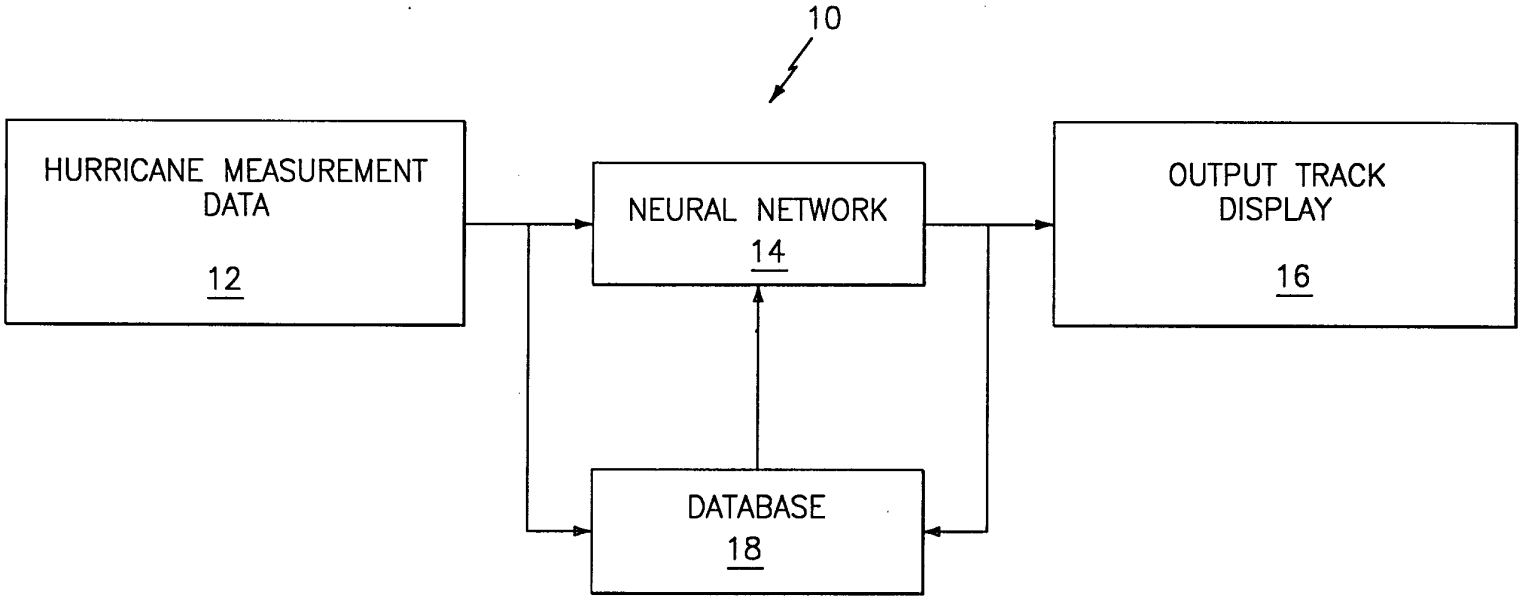

10
HURRICANE MEASUREMENT DATA
12
NEURAL NETWORK
14
OUTPUT TRACK DISPLAY
16
DATABASE
18

FIG. 1

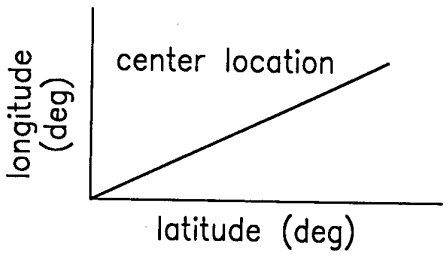


FIG. 2(a)

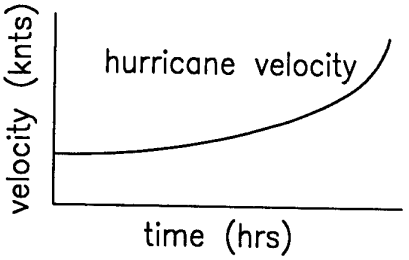


FIG. 2(b)

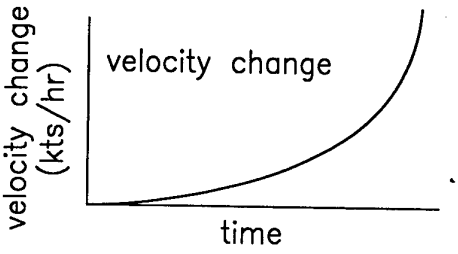


FIG. 2(c)

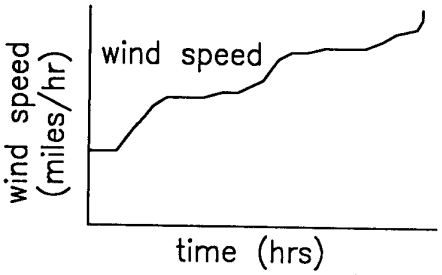


FIG. 2(d)

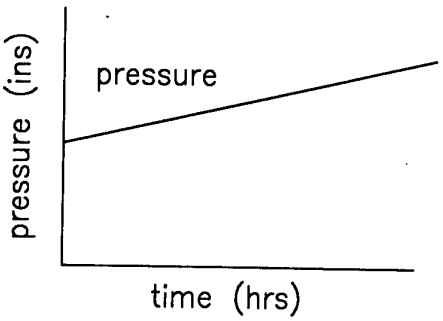


FIG. 2(e)

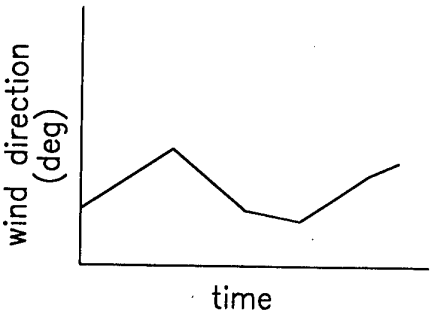


FIG. 2(f)

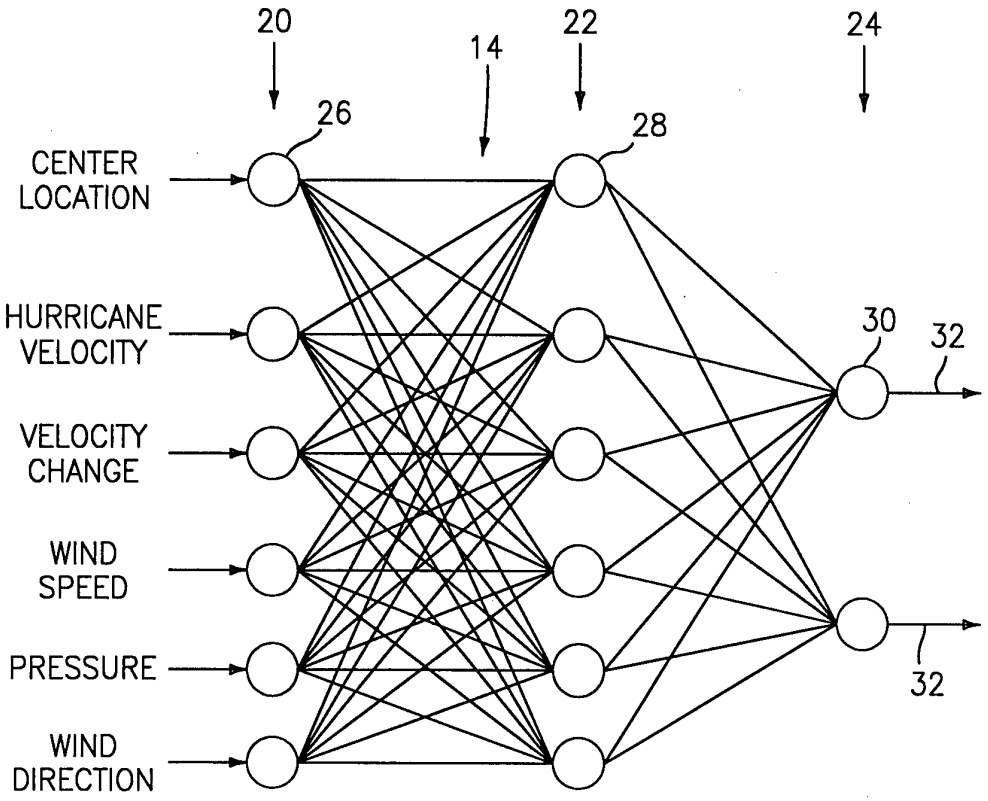

20
14
22
24
26
28
CENTER LOCATION
HURRICANE VELOCITY
VELOCITY CHANGE
WIND SPEED
PRESSURE
WIND DIRECTION
30
32
32

FIG. 3

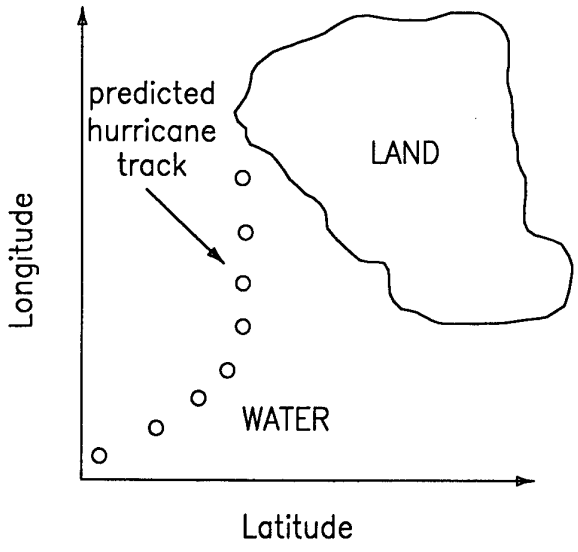

predicted hurricane track
LAND
WATER
Longitude
Latitude

FIG. 4