ORIENTAL JOURNAL OF
COMPUTER SCIENCE & TECHNOLOGY
An International Open Free Access, Peer Reviewed Research Journal
www.computerscijournal.org

ISSN: 0974-6471
December 2011,
Vol. 4, No. (2):
Pgs. 361-369

Automatic Fault Detection in JC Bamford (JCB) Machines in a Construction Industry by the Application of Neural Network System

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(Received: November 06, 2011; Accepted: November 29, 2011)

ABSTRACT

Automatic fault detection is mainly for applications in the automotive industry. A fault detection system based on multivariate data analysis is needed to increase data reliability and for the purpose of monitoring and controlling of test equipment. The detection scheme has to process different measurements at a time and check them for consistency. An important requirement for the fault detection scheme is that it should be able to automatically adapt itself to new data with high level of accuracy that may not always be achieved manually. The project related to this paper was intended to work on real-time parameters read from high power automotives, especially JCBs used in construction industry. Various parameters including: temperatures; pressures; oil levels; states of the valves are monitored and sent to a server. Results showed that automatic fault detection through neural network system is useful as it saves time, cost and detects faults accurately.

Key words: Multivariate data analysis; Fault detection; Automotives.

INTRODUCTION

A fault in a machine can easily be detected by its operator, if acquainted with it for a long period, by analyzing the symptoms he confirms a defect. This could be on the basis of its sound, speed, etc. The project related to this paper is intended to work on real-time parameters read from high power automotives, especially JCBs used in a construction industry. Various parameters including temperatures, pressures, oil level, and states of the values are monitored and sent to a computer server. These parameters are then used to analyze the health of the system.

A training and testing (real time detection) were conducted and when a set of parameters are fed, the system should be able to detect the faults (if any) from its previous experiences

Literature Review

In principle, NNs can compute any computable function, i.e., they can do everything a normal digital computer can do[21, 19, 14, 20] or perhaps even more, under some assumptions of doubtful practicality[18, 7]. There have been attempts to pack recursive structures into finite-dimensional real vectors[3, 16, 4, 5, 15, 8]. Obviously, finite precision limits how far the recursion can go[7]. The practicality of such methods is open to debate. Ripley[17] discussed a variety of neural network methods such as tree-based methods and belief networks. He used numerous realistic examples in his book about neural networks.

Mie and Tong-Seng[12] presented the application of neural networks in software quality estimation using object-oriented metrics. Jakubek and Strasser[11] studied an automatic fault detection scheme for application in the automotive industry. Ahmad *et al*.[1] discussed the application of artificial neural networks in the area of process monitoring, control, and fault detection. Adyles and Fabricio[2] studied automatic faults diagnosis by application of NN system and condition-based monitoring using vibration signals. Hinton[10] networks of artificial neurons modeled on conventional computers are helping explain the ability of the brain to process and retain information.

System Analysis

Scope of the project

Machine monitoring, fault detection, and diagnosis are very important and difficult topics in the engineering field. With proper machine monitoring and fault detection schemes, improved safety and reliability can be achieved for different engineering system operations. The importance of incipient fault detection can be found in the cost savings which are realized by detecting potential machine failures before they occur. Non-invasive, inexpensive, and reliable fault detection techniques are often preferred by many engineers.

Many of the inexpensive and noninvasive techniques available for fault detection and diagnosis in machines are based on mathematical models of the system of interest, such as parameter estimation (model based techniques). However, since most machine dynamics are non-linear and stochastic, many assumptions must be made regarding the system in order to arrive at a simple and reasonable mathematical model of the machine.

The project related to the paper can be proved useful as it saves us a lot of time and money as we are able to rely on the accuracy of its detection. This level of accuracy may not always be achieved manually. In other words, the fault detection or diagnosis system is not robust enough in the presence of noise and perturbations because the underlying mathematical model of the system is not well represented.

System description

The system mainly consists of the machine side and the system side. The machine side consists of embedded board and supporting circuitry, GSM modem, and external antenna.

The embedded board is a microcontroller (PIC16F87X or PIC16) which contains an LCD and its function is to sensor the parameters of the machine and sends those censored data to a modem. It is installed in the machine itself. It can store data up to 1GB. The LCD is to display the message (error report) from the processing system to the operator. When there is a message to the operator, it sounds an alarm so that the operator can notify the message.

The embedded PIC16 microcontroller chip sends the parameters dynamically to the GSM modem and the modem actually sends the parameters to the processing system using File Transfer Protocol (FTP). It is interfaced with the PIC board through an integrated Serial port and its standard is RS232. Here the bits are send in a serial fashion.

The External Antenna is a magnetic bound type antenna. It sends the data bits from the modem to the receiver of processing system serially. It is connected the GSM Modem through SMA Female Connector.

The processing system part consists of:

- FTP Reception System
- Work Station/Processing System
- GSM Modem

It is the FTP Reception System to which the modem of the machine sends it data using FTP Protocol. Then it performs error handling to overcome the error during the transmission. The work station gets the data received at the FTP reception system to a database and feeds them to the NN which is already trained by the system administrator. For that those systems are connected via Remote DB Connectivity. It analyzes the given data with the trained data and obtains the output and then produces an error report which is send back to the PIC of the machine and it rings an alarm in the machine in the case of any error.

The GSM Modem receives the parameters send by the machine's embedded board through antenna which interfaced to the modem similar to the machine side. It can also send messages to the machine side serially. Figure 1 shows a diagrammatic presentation of the entire system.

Existing System

There are any of the inexpensive and noninvasive techniques available for fault detection and diagnosis in machines are based on mathematical models of the system of interest, such as parameter estimation (model based techniques). However, since most machine dynamics are non-linear and stochastic, many assumptions must be made regarding the system in order to arrive at a simple and reasonable mathematical model of the machine.

Many of the inexpensive and noninvasive techniques available for fault detection and diagnosis in machines are based on mathematical models of the system of interest, such as parameter estimation. Machine in construction fields like JCB has so many working parameters like main gauge pressure, oil pressure, air pressure, engine temperature, valve statuses, etc.. in which most of them are digital values and some are analog values like oil pressure, air pressure, engine temperature which are varying mostly in a non linear fashion, which cannot be implemented using simple if- else logic. The existing system is mainly based on reasonable mathematical assumptions and that may not be accurate all the time. For example if the air pressure increased quickly and after a short period of time it becomes normal. For the existing system this case will be considered as a serious problem even if it is not a problem.

The existing system has some demerits such as it can't guarantee accuracy since it uses the idea of fussy logic, it requires a high degree of human effort and the administrator must be an expert person to identify the fault in the machine by examining the parameter values, and the administrator has to sit at the workstation all the time since the parameter data send continuously from the machine.

Proposed System

The emerging artificial neural network technology has been applied successfully to perform monitoring and fault detection of different engineering systems, such as motors and machine systems. The demand for the use of artificial neural networks to solve engineering problems is expected to increase significantly in the next ten years, due to several breakthroughs in this field and also to the limitations of the conventional engineering problem solving techniques.

Artificial neural network configurations, training data requirements, robustness issues, and design considerations of motor fault detection were

Table 1: Electrical characteristics of the GSM Modem

Electrical Characteristics	Minimum	Typical	Maximum	Units
Supply Voltage	5	-	32	V
Supply Current:				
´ In communication	-	450		mA
´ Idle mode	-	23		mA
´ Idle mode with RS232 power saving	-	13		mA

investigated. Results to date have demonstrated their significant performance advantages relative to the conventional methods. Here we are mainly concentrated on machine in construction fields like JCB. The working parameters of the JCB while it is running are sent to the workstation which is implemented by Neural Network. The workstation will analyze the parameters and find out the problem currently in the machine and sends a report at the same time.

There are some advantages in the proposed system such as it is more accurate than the existing system by using the ANN Technology, it avoids huge loss of money and work due to machine's faulty conditions. It correctly monitors the working condition of the machine and sends the message reports almost at the same time so that the operator can suddenly switch off the machine. It reduces human efforts by avoiding the manual fault detection and there is no need for the administrator to sit with the workstation all the time. However, the proposed system identifies only the faulty condition in the machine; there is no solution provided for that fault. To send reports to and from the machine, we are using a GSM modem which contains a SIM for communication of a particular network. Here the message delivery and the transfer rates are mainly depend upon the network strength and performance and there should be sufficient credit in the SIM account. If there is any violation to these two conditions, the machine and system sides will go down.

Technology

Neural Network (NN) technology is used in the study. There is no universally accepted definition for neural networks. But perhaps most people in the field would agree that NN is a network of many simple processors (units), each possibly having a small amount of local memory. The units are connected by communication channels (connections) which usually carry numeric (as opposed to symbolic) data, encoded by any of various means. The units operate only on their local data and on the inputs they receive via the connections. The restriction to local operations is often relaxed during training. According to the *DARPA Neural Network Study* [6] "*a neural network is a system composed of many simple processing elements operating in parallel whose function is*

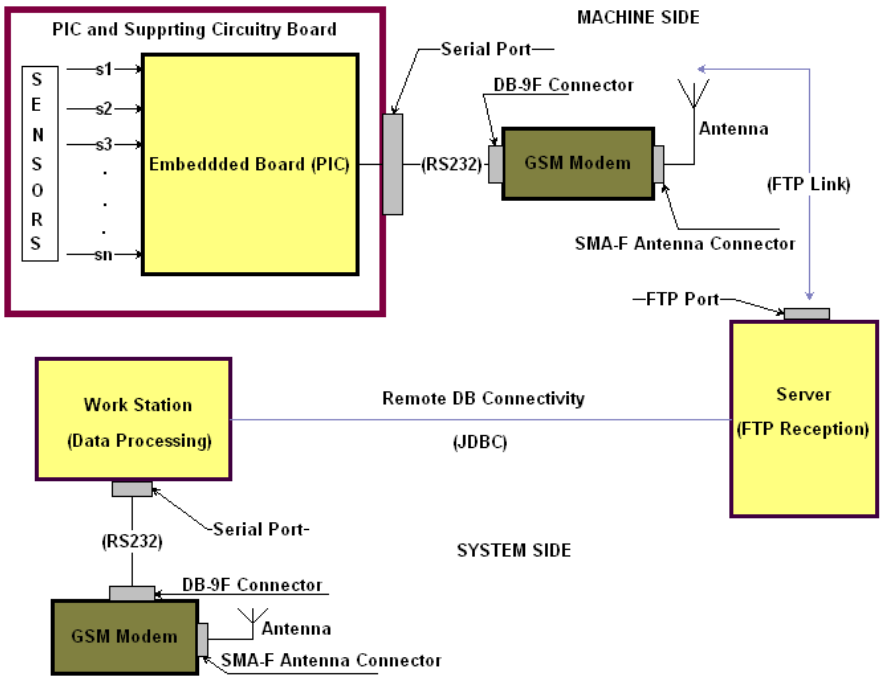

Fig. 1: Hierarchical diagram of the entire system

determined by network structure, connection strengths, and the processing performed at computing elements or nodes".

According to Haykin[9] A neural network is a massively parallel distributed processor that has a natural propensity for storing experiential knowledge and making it available for use. It resembles the brain in two respects:

1. Knowledge is acquired by the network through a learning process.
2. Interneuron connection strengths known as synaptic weights are used to store the knowledge.

According to Nigrin[13] A neural network is a circuit composed of a very large number of simple processing elements that are neurally based. Each element operates only on local information. Furthermore each element operates asynchronously; thus there is no overall system clock". According to Zurada[22] Artificial neural systems, or neural networks, are physical cellular systems which can acquire, store, and utilize experiential knowledge. Figure 2 is a typical neural network system.

Data features

- Data circuit asynchronous, transparent and non transparent up to 14,400 bits

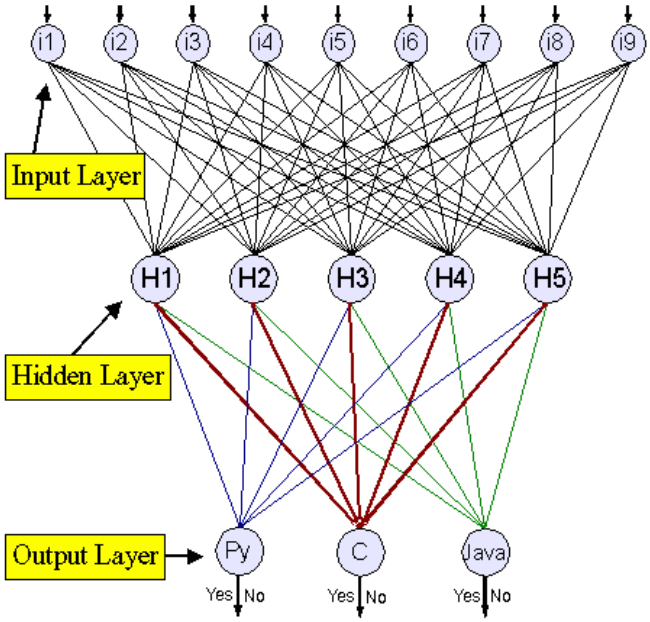

Fig. 2: Typical Neural Network System

Short Messages Services features

- Text and PDU
- Point to point (MT/MO)
- Cell Broadcast

Technical Specifications

- Max Storage Temperature -10°C to +70°C,
- Max Operating Temperature -15°C to +50°C
- Dimensions 88mm x 60mm x 26mm
- Weight 100grams

Electrical Characteristics

Table 1 indicates the electrical characteristics of the GSM modem

Interfaces

- SIM holder (integrated Drawer, accepts standard SIM card)
- 15 pin Sub-D type connector (for serial and audio connection)
- 4-pin power supply connector (micro-FITTM)
- SMA antenna connector (50 ohm)

Power Supply Unit

- Input: 110-240Vac, 2 pin IEC connector
- Output: 12Vdc +/-5%, 1A, 4 Pin micro-FITTM connector

Status indicator

The LED will indicate different status of the modem: circuitry

- Off Modem switched off
- On Modem is connecting to the network
- flashing slowly Modem is in idle mode
- flashing rapidly Modem is in transmission/ communication (GSM only)

Hardware and Software Requirements

Hardware requirements

*PIC16F87X or PIC16***.** It is nothing but a microcontroller chip. It is embedded within the machine that our system is going to monitor. It sends the parameters of the machine dynamically to a modem and from it our system gets the data which determines whether the machine working properly or not. It is with the following specifications:

PC16's Core Features

- High-performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
- DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory,
- Up to 368 x 8 bytes of Data Memory (RAM)
- Up to 256 x 8 bytes of EEPROM data memory
- Pinot compatible to the PIC16C73B/74B/76/ 77
- Low-power, high-speed CMOS FLASH/ EEPROM technology
- Fully static design
- In-Circuit Serial Programming (ICSP) via two pins
- Single 5V In-Circuit Serial Programming capability

Low-power consumption

- < 2 mA typical @ 5V, 4 MHz
- 20 mA typical @ 3V, 32 kHz
- < 1 mA typical standby current

Other hardware requirements

- Processor : P1V or above
- RAM : 512 or above
- HDD : 40 GB or above
- CDROM

Software requirements

The operation system can be any OS. Other development tools are, JAVA and SQL Server be the back end.

System Design

The major functions in the system are

FTP Reception

The PIC16 embedded within the machine sends the parameters to the GSM Modem, which forwards the data to the processing system through File Transfer Protocol (FTP). This function will receives the file which is send by the modem. The delimiter of each frames are also checked in this module.

Error Check

Checks the integrity of data received from the modem. The major steps are Packet Checking, Format Checking, and Retransmission upon ambiguous packet reception.

Database Retrieval

After getting the parameters from the modem, they are stored into a database. Our Neural Network Processing system will take the data from this database.

Neural Network analysis

This module will process the data retrieved from the database for detecting the error of the machine. The administrator first trains the Neural Network with some possible sets of input parameters and the system will give the output by analyzing the input data with trained information.

Result Creation

After processing the fed input to the Neural Network system, we have to prepare the Error Report which is send to the machine's embedded system by which the operator can get the result.

Module Description

A *module* can be viewed as a separate

part of the project which accomplishes a particular task. There are seven main modules in the project. They are:

Fault detection system

There are several sensors connected at the machine side. These sensors sense the information about different parameters (3 analog parameters and the rest are digital). The sensor data is then sent to the PIC. The PIC is used to convert the sensor data into digital values.

FTP Handler

Here, the data from the PIC is sent to the modem. By using AT commands, the PIC controls the modem. The data from the modem is then sent to the workstation by using FTP.

Error Handler

Error handler mainly checks the integrity of the message. There are three main functions:

Error checking

It checks whether the received message is completed by checking for a starting and ending character in the message.

Format checking

It checks the format of the received message.

String handler

It converts the received data into a string of bits and passes it to the database handler for processing.

Database Handler

The checked data and the trained parameters of the system are stored here .During processing, it is taken from the database.

Neural Network

Here, the received set of data (parameters), is compared with the required values. If they match, there is no error else the presence of error is confirmed.

Training

The neural network is trained to identify a set of correct data and a set of faulty data. The learnt parameters are stored.

Result generation

Depending on the output from the neural network module, it creates an error report which is then send to the machine operator.

System Test Plan

A test plan is a systematic approach to testing a system such as a machine or software. The plan typically contains a detailed understanding of what the eventual workflow will be. A test plan documents the strategy that will be used to verify and ensure that a product or system meets its design specifications and other requirements. A test plan is usually prepared by or with significant input from Test Engineers.

Depending on the product and the responsibility of the organization to which the test plan applies, a test plan may include one or more of the following:

Unit Testing

The software is tested using the unit test method. Unit testing focuses verification effort on the smallest unit of software design module. Using the procedural design description as a guide, important control parts are tested to uncover errors within the boundary of the module.

Integration Testing

This testing is the systematic technique for constructing the program structure by performing the test in each module and later combining the entire individual module to form a very large program.

Validation Testing

Validation testing is the process of testing the input to find whether the given inputs are valid or invalid.

System Testing

System testing was performed to verify that all system elements have been properly integrated and perform allocated function. Security testing was done to check the security mechanisms built into the system, which will protect it from improper penetration. Performance testing was done to test the runtime performance of the software, for user acceptance.

Acceptance Testing

The system considered is tested for user acceptance. The software should keep in touch with perspective system; user at the time of developing and making changes whenever required. This is done with regard to input screen design, output screen design, online message to guide user and the like.

Regression test

To be performed on an existing operational product, to verify that existing functionality didn't get broken when other aspects of the environment are changed (e.g., upgrading the platform on which an existing application runs. Test plan document formats can be as varied as the products and organizations to which they apply, but there are three major elements of a test strategy that should be described in the test plan: Test Coverage, Test Methods, and Test Responsibilities. Test coverage in the test plan states what requirements will be verified during what stages of the product life. Test Coverage is derived from design specifications and other requirements, such as safety standards or regulatory codes, where each requirement or specification of the design ideally will have one or more corresponding means of verification. Test coverage for different product life stages may overlap, but will not necessarily be exactly the same for all stages. For example, some requirements may be verified during Design Verification test, but not repeated during Acceptance test. Test coverage also feeds back into the design process, since the product may have to be designed to allow test cases.

Test Reports

A test plan is a systematic approach to testing a system such as a machine or software. The plan typically contains a detailed understanding of what the eventual workflow will be. A test plan documents the strategy that will be used to verify and ensure that a product or system meets its design specifications and other requirements. A test plan is usually prepared by or with significant input from Test Engineers.

CONCLUSION

Any person can understand the fault in a machine by his experience that is by hearing its sound while working, by watching its oil level etc. But it may not be correct. Here we are automating the fault detecting process by making use of artificial neural networks, so that the machine can directly send the parameters to the processing system and get the most accurate result about the current state of the system.

ACKNOWLEDGEMENTS

The author gratefully acknowledged the entire faculty of the Computer Science Department at Adi Shankara Institute of Engineering and Technology (ASIET) for their valuable support and encouragement in conducting this project.

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