Fault Diagnosis System of Hydraulic System Using Lab Windows/CVI and Virtual Instrument Technology

Huanliang Li
PLA Univ. of Sci. & Tech.
No. 88, Houbiaoying road, Nanjing 210007, China

Xiaoqiang Yang
PLA Univ. of Sci. & Tech.
No. 88, Houbiaoying road, Nanjing 210007, China

Yaming Gao
PLA Univ. of Sci. & Tech.
No. 88, Houbiaoying road, Nanjing 210007, China

Abstract

Due to the electro-mechanical and electric-hydraulic coupling as well as structure complexity of hydraulic system of engineering equipment, its fault diagnosis is difficult to be implemented. Therefore a novel fault diagnosis system is introduced in this. It consists of host computer, portable test platform, signal adapter unit, test interface and connection cables. Its hardware platform encompasses host computer, universal fault test and diagnosis platform, PXI-bus data acquisition system, signal conditioning circuits, power supply system, interface unit, connection cable and peripheral dedicated test equipments. Ant its software is developed by C and Lab Windows/CVI based on Win32 operating system. The software consists of three parts: the main control and management software module running on test and diagnosis platform, the data acquistion modules operating on signal adapter unit as well as the remote interface software module. The fault diagnosis system can perform fault diagnosis of hydraulic excavator on replaceable circuit board and block of the hydraulic system or electrical system. It can also help equipment repairmen and operator accomplish quick repairs and maintenance for the hydraulic system and electronic control system of military engineering equipment

Keywords: virtual instrument, Lab Windows/CVI, fault diagnosis, hydraulic system, interface adapter unit

1. Introduction

Most of military engineering equipment, such as GJT112 bulldozer, has been equipped with electronic monitoring devices. These devices carries out operating state monitoring and alarming function for engine system, hydraulic system, pneumatic actuation system and electrical equipment system of construction machineries [1, 2]. In general these devices can not store and process the large amount of monitoring data. However, the presented intelligent fault diagnosis system in this paper could meet the equipment user's needs for state monitoring and fault diagnosis of electrical control system and hydraulic system. It can implement state detection and fault diagnosis to the electrical control system of hydraulic excavator for readiness of military operation. Furthermore the fault would be located on standalone unit. The state parameters of hydraulic and electrical system are acquired through built-in test port. Consequently, the fault diagnosis system can support data information for the fault diagnosis of the hydraulic and electrical systems of military engineering equipment.

2. Design of the fault diagnosis system

In order to meet the above needs, the fault detection system can not only test the analog and digital output signal of various components as well as the communication signal between every subsystem of the hydraulic excavator, but also provide virtual excitation signals for the system under test of hydraulic system and electrical system.

It therefore performs the work excitation function of electrical control system and fault diagnosis of the hydraulic and electrical system. Accordingly, it adopts the overall technical scheme of portable detection and diagnosis platform, adapter, test interface and test cable. The field fault diagnosis system's hierarchical structure is illustrated in figure 1. It can carry out the performance test and fault diagnosis for the electrical system and hydraulic system of crawler hydraulic excavator. And it can also locate the fault to the replaceable unit of control board, block as well as corresponding hydraulic parts and subsystem.

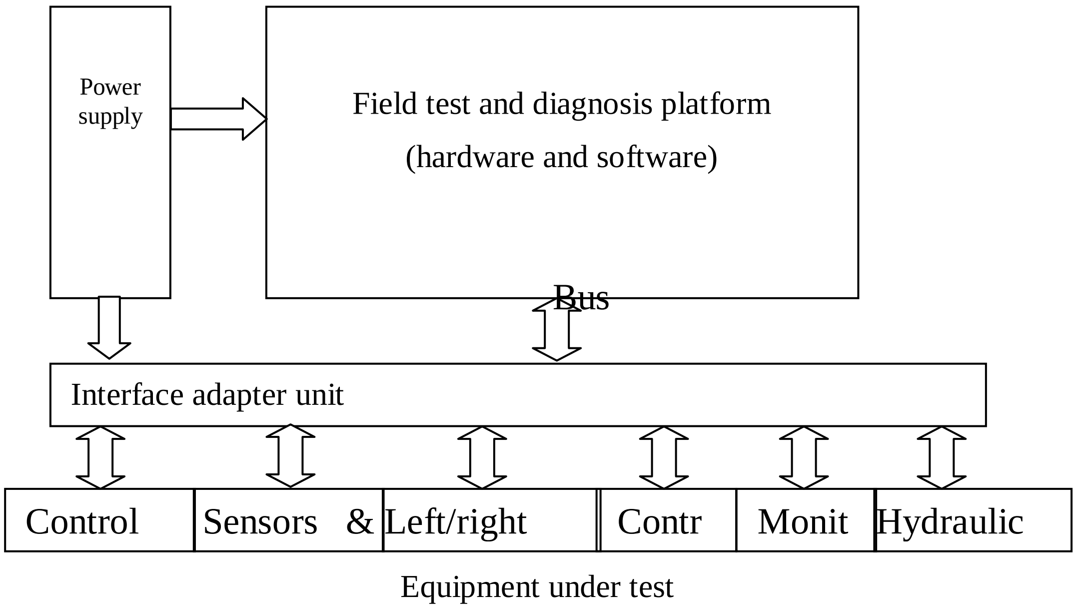

Fig.1 Architecture of fault diagnosis system

3. Hardware platform

3.1 Field test and diagnosis platform

The fault test and diagnosis platform can accomplish its function with host computer- PC. The virtual instrument platform is the central unit. It uses hardware structure of PXI chassis, master controller and PXI modular instruments ensuring the system requirements of opening and expansibility. It is actually equal to a dedicated computer installed special data acquisition and signal conditioning modules. Windows operating system is also running on it. In addition, it use PXI-8420 serial module to communicate with the adapter unit. The software of the platform is developed based on its operating system. The hardware resource configuration is presented in table 1.

Table 1. Hardware resource configuration

Instrument	Type	Feature
PXI chassis	NI PXI-1042	8-slot 3U PXI Chassis with Universal AC
Embedded controller	NI PXI -8187	2.0 GHz Pentium M 760， Windows XP
Data acquisition (DAQ) board	NI PXI-6259	32 SE/16 DI · 1.25 MS/s, 4 · 2.86 MS/s,48 DIO
Industrial Digital I/O module	NI PXI-6509	96 bidirectional digital I/O, 5 V TTL/CMOS
Serial Interface	NI PXI-8430	High-Performance, 8-Port Serial Interface
Switch module (multiplexer)	NI PXI-2530	8 banks of 16x1 (1-wire)

3.2 Interface adapter unit

(1) Structure design

The interface adapter unit serves as a versatile signal connection bridge between control computer and equipment under test.

It supports various data types—analog, digital, and serial—and functions as a dual redundant system with auto failover capability. It connects with the equipment under test by cable. One end of the interface adapter unit is connected to equipment under test by cable, and the other end is connected to the computer system by VPC 90 interface system. Therefore the command of control computer is translated to excitation signal needed by test. The external response signal form equipment under test is also translated into signal acceptable to the control computer and supplied to the test program module for diagnosing and displaying.

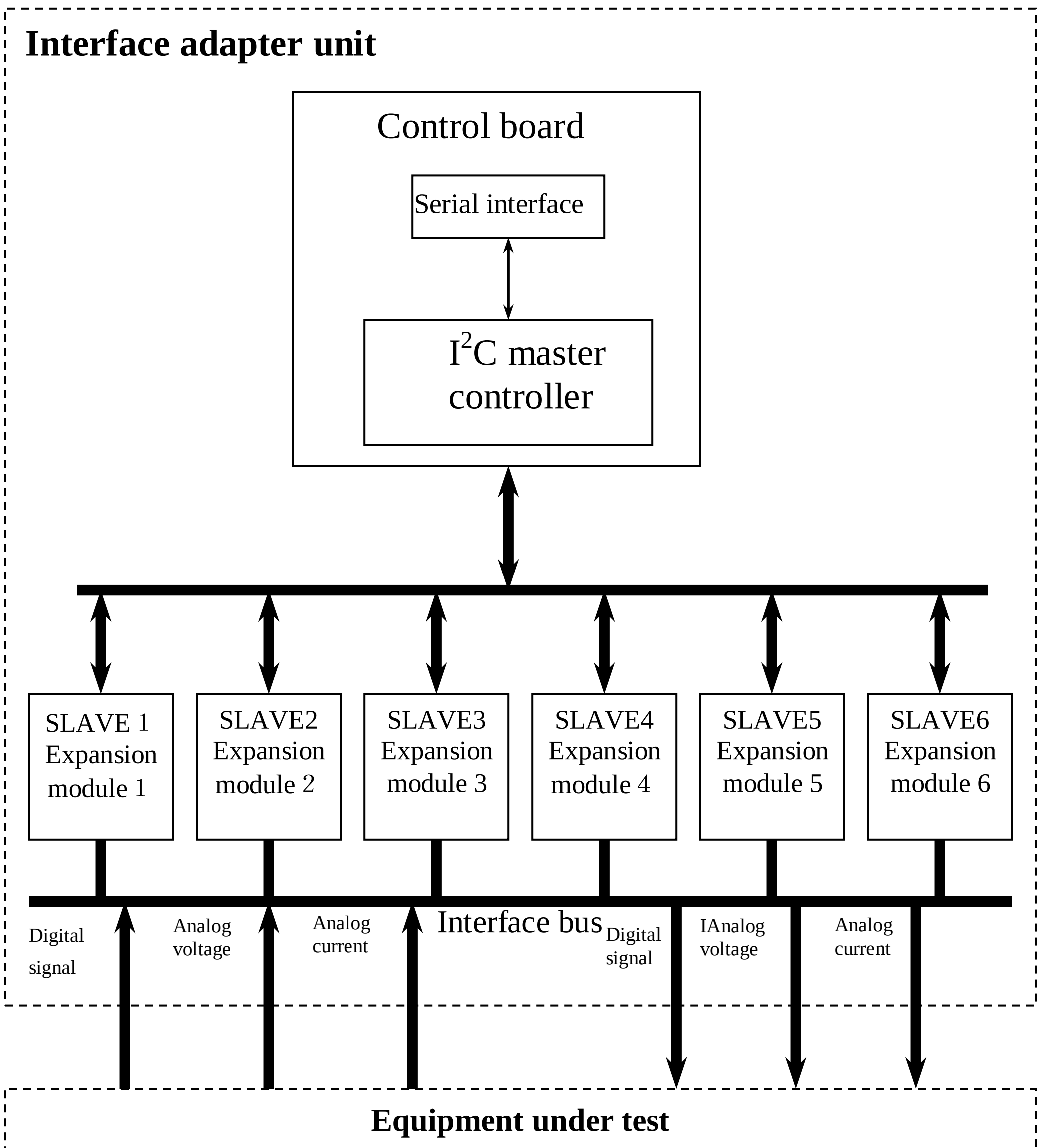

Fig.2 Hardware block diagram of interface adapter unit

The interface adapter unit is composed of control board and expansion modules as indicated in figure 2. The control board receives the control command from control computer and allocates the transformed data to expansion modules. It acquires the data of expansion module and translated them to control computer for processing and display. The expansion modules serve as the interface between adapter and equipment under test. It performs the data acquisition of digital and analog signal as well as provides the analog and digital excitation signal needed by test. The interface adapter unit's modular object-oriented design enables its flexible and powerful function of fault detection and diagnosis.

(2) Signal conditioning module

The input signals of fault detection and diagnosis system includes digital, voltage and current signals. Correspondingly, the output signals include digital, SPST relay, voltage and current output. All the signal conditioning modules are connected to I2C bus as slave devices to be controlled by the I2C controller on main control board.

The digital input signal is transferred to DI terminal of 16F74 by photoelectric coupling isolation as indicated in figure 3. The -10 to 10 V analog voltage signal is converted into 0-5V and transferred to 16F74 as indicated in figure 4. The current signal conditioning circuit is described in figure 5. The current input signal is transformed to voltage signal and transferred to AD converter. Rs is sample transistor. A voltage will result across Rs due to current passing through it, then the voltage is amplified by LM224 and passed to analog input terminal of 16F74 as indicated in figure 5.

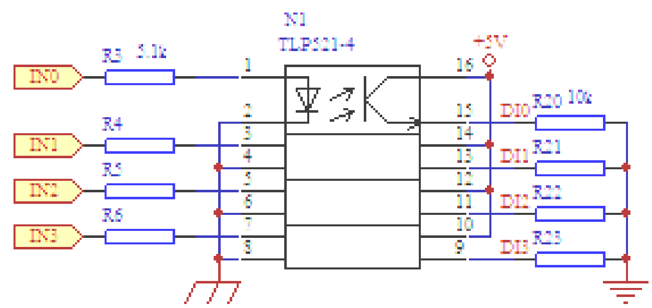

Fig. 3 Conditioning circuit of digital signal

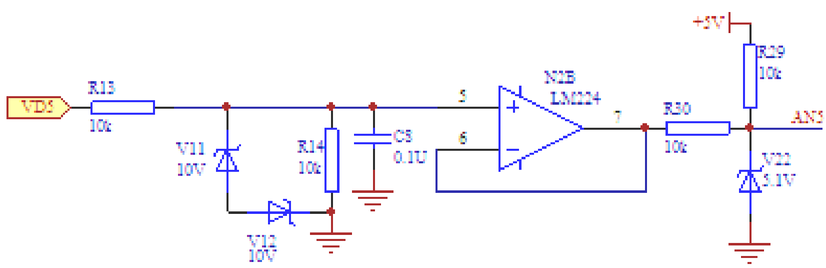

Fig. 4 Conditioning circuit of analog voltage signal

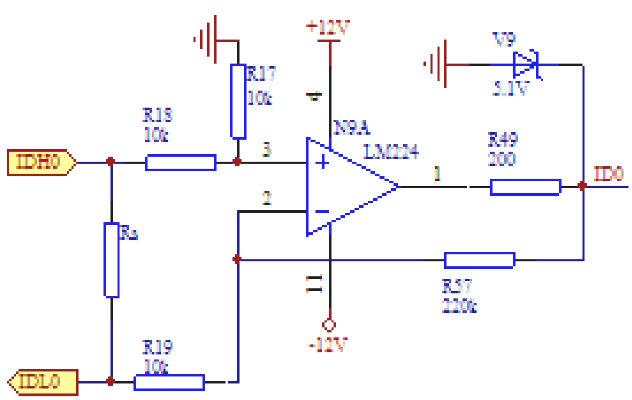

Fig.5 Conditioning circuit of current signal

The output signal of the interface adapter unit includes digital, relay and analog voltage signals. Low power output digital signal is converted to current signal up to 20mA driving capability as indicated in figure 6. When a high current signal is needed, the output signal controls the relay to accomplish the signal switching by ULN2003 driver module. A ULN2003 can manipulate 7 relays. The analog output signal conditioning is realized by use of digital potentionmeter. CAT5113 is 100 wiper steps potentionmeter. The input pulse adjusting voltage signal is connected to INC pin. The input signal of UD pin determines the adjustment direction of the potentionmeter. The final output circuit is an emitter follower composed of triode and resistor. Analog output conditioning circuit is demonstrated in figure 7.

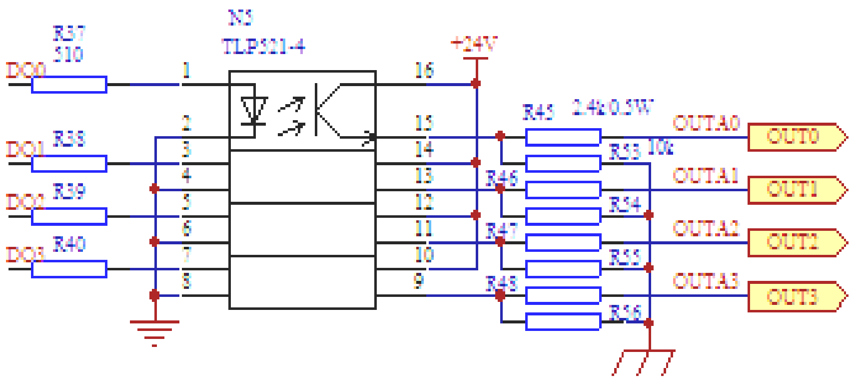

Fig.6 Low power digital output conditioning circuit

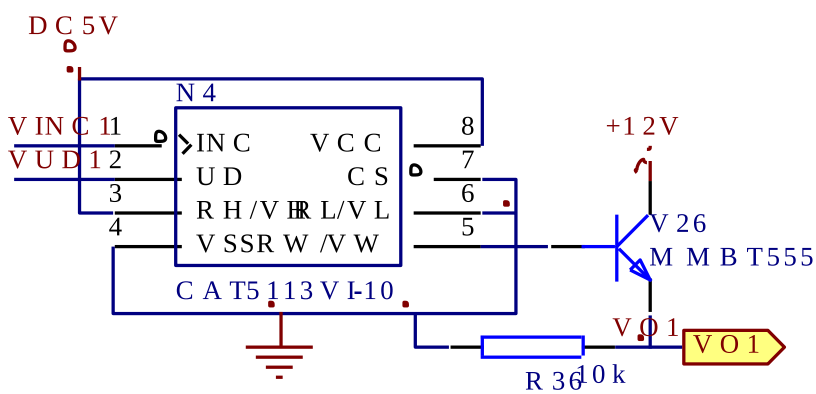

Fig.7 Analog voltage output conditioning circuit

4. Software development

The software of fault diagnosis system consists of two parts: test software module and remote display software module. The test software carries out the parameter test, data record and analysis. The remote display software is linked to fault detection and diagnosis software through TCP/IP protocol. It receives test information and displays the test process timely. The fault detection and diagnosis software includes 14 internal modules, and load 2 ACCESS database file: Rec.mdb and Repair.mdb.

4.1 Software structure

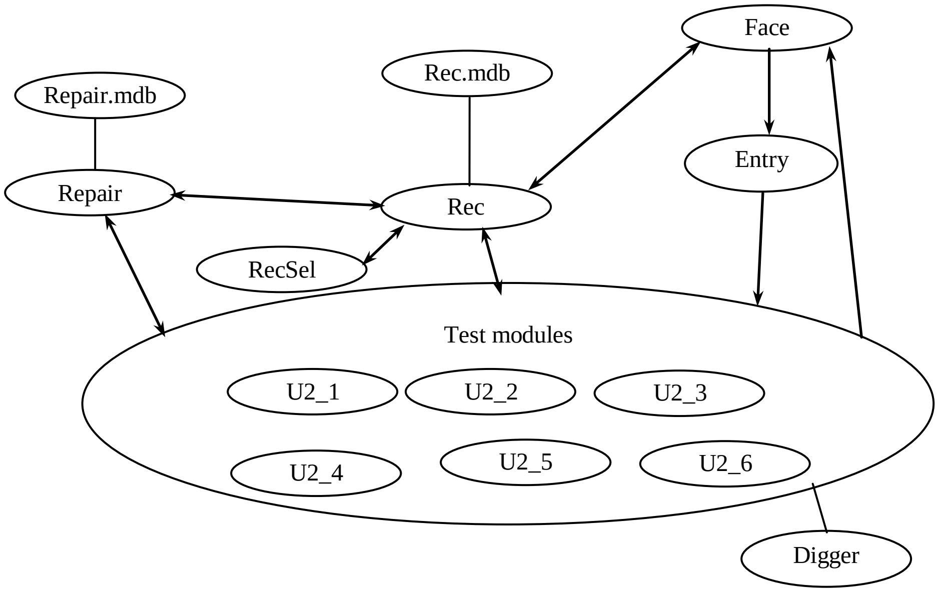

Fig.8 Software architecture of fault detection and diagnosis

The software modules are described in figure 8. Face of this program is the top level module. Entry is that of the test entry module. Digger.c is the common function module. Rec is the record and search module. RecSel is the module of record selection. Repair the maintenance and repair module. Database is the module of database.

The program will enter into Face module after start. According to the needed test type the program enters into Entry module. User selects time and data to form the index item of the Rec.mdb. In addition, the information of user and equipment under test is entered for data recording. Face module also provides the entry point of record. Digger module includes the common functions.

There are 7 test modules: U2_1、U2_2、U2_3、U2_4、U2_5 and U2_6 modules. They manipulate the test of left/right handle, left/right armrest box, controller, sensors and switch, monitor as well as hydraulic system. All test modules have the identical flow structure.

3.2 User interface

The main interface includes entry panel, test panel, record panel and repair guidance panel. The test interface is designed by universal format. The sensors and switches are taking as an example as indicated in figure 9. The test panel is divided into three sections: graph display, test procedure and result display as well as manipulation area. The graph display area indicates the current signal status. The display format is in universal mode as follows.

The state signal and double status digital signal under test are shown in round indicator. Indicator light on indicates logic 1, and light off indicates logic 0. Three states signal is indicated by round indicator of green, red and black color. Two states excitation signal is described by square indicator. Indicator light on represents logic 1 and light off represents logic 0. The input and output of analog signal is manipulated by digital display control. The transferred ASCII code is present by text box.

Every test step is described by table format in test procedure and result display area. Fault detection result and solution are present too. This data format is easy to record and processing for the maintenance and repair guidance. Manipulation area has six keys: start test, stop test, fault diagnosis, data storage, data display and return. Key is activated by left-click event.

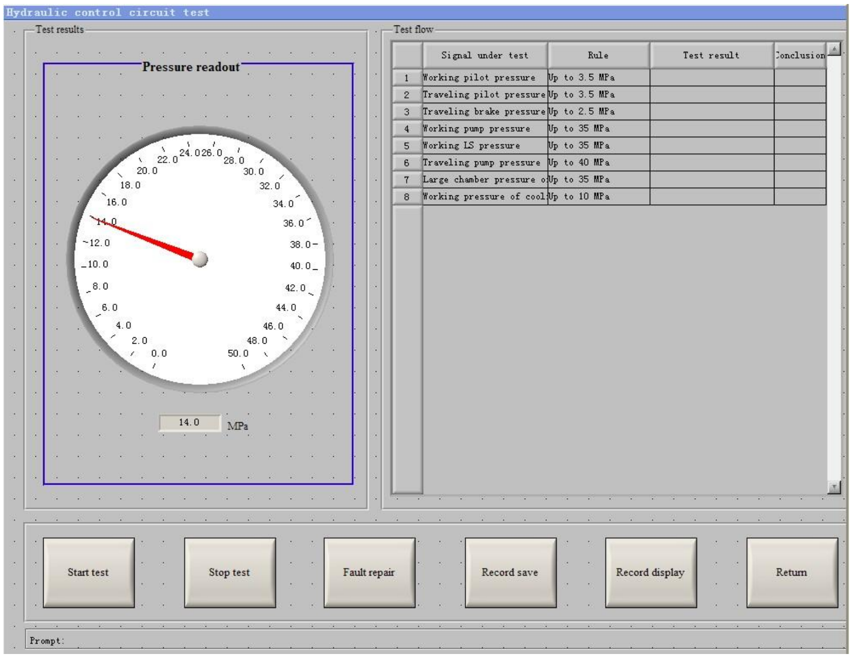

Fig.9 Main panel of test program

4. Conclusion

The fault diagnosis system presented in this paper can acquire, process and diagnose the performance parameters and faults of the electrical system and hydraulic system. Its modular, object-oriented design enables proper hardware structure, hierarchical effective software, comprehensive software testing content, accurate and reliable analysis and diagnosis, high performance stability and powerful maintainablity. In addition, the design of shielded cable facilitates external noise isolation. And the anti-inserted plug of cable enables the safety and reliability of test. This system pretty well resolves the current difficult problem of fault maintenance and detection for the hydraulic crawler excavator. It implements the rapid test and repair guidance of hydraulic system and electrical system performance for the excavator. Thus it maintains the integrity of military equipment and enhances the fighting capability of equipment.

References

Zhengzhou Yutong Group Ltd., Technical manual of GJT112 type bulldozer. Yutong Ltd., 2006.

Guizhou Jonyang Kinetics Co Ltd., Technical handbook of GJW111 type excavator, Jonyang Kinetics, 2004.

Wu Bo, Ma Yuxiang et al. Expert System (Modified version). Beijin: Qsinghua university press, 2008 (in chinese).

Robert N. Goldberg and Sholom M. Weiss. An experimental transformation of a large expert knowledge base. Journal of medical systems, Vol. 6, No. 1, 1977: 41-52.

Li Qinghai, Zhu Xinhua. Fault diagnosis expert system of the fire-control system based on hierarchical analysis. Journal of Electronics Optics & Control, 2006 (8): 28-34

Vesely, William; et. al. (2002) (pdf). Fault Tree Handbook with Aerospace Applications. National Aeronautics and Space Administration. Retrieved 2010-01-17.

Joseph C. Giarratano, Gary D. Riley, “Expert Systems: Principles and Programming”, Fourth Edition.Course Technology; 4 edition (October 15, 2004).

Documents associated with Production Rule Representation (PRR), Release date: December 2009. http://www.omg.org/spec/PRR/1.0/

James D. McCarthy, Phil A. Graniero and Steven M. Rozic, “An Integrated GIS-Expert System Framework for Live Hazard Monitoring and Detection”, Sensors, 2008, 8, 830-846.

Liu Fujun, Li Hua et al. The tree construction algorithm study based on binary tree. Journal of coputer technique and development (in chinese). 2006. 07.