The Nexsys™ Realtime Risk Management System for Advanced Decision Support

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ABSTRACT

Mining has gained a reputation as a hazardous industry; in response to this the Nexsys™[1] Realtime Risk Management System has been developed for decision support.

The prominent features of Nexsys™ system are: a novel risk profiling matrix based on industry standards that provides decision support to control room operators, the ability of Nexsys™ to analyse a large amount of disparate mine data in real time, a rule engine that triggers alarms and changes the risk profile matrix and the client-server architecture allowing clients to be located worldwide, including on any web-enabled device. A novel predictive data analysis function is currently under development.

The user interface enables a multitude of data views in 2- and 3-dimensions with displays catered to a client's requirements.

The Nexsys™ system was successfully demonstrated at 3 mine sites in 2005-2006: the Grasstree and Beltana Coal Mines in Australia and the Kushiro Coal Mine in Japan.

If properly implemented, Nexsys™ has the potential to assist the international mining community in improving safety performance as a hazard management support system.

Keywords: Nexsys™, Decision Support, Risk Management, Underground Coal Mining, Data Integration

1. INTRODUCTION

The U.S. Mine Safety and Health Administration reported 299 fatalities in the U.S. alone in coal and metal/non-metal mining industries combined between 2003 and 2007 [1]. These statistics, however, are insignificant in comparison to safety records of Chinese coal mines alone where the official fatality statistics ranged from 5,602 to 6,995 deaths annually in the last decade, with independent experts claiming a much higher actual death toll as mine owners routinely falsify death counts in order to avoid mine closures or fines [2]. It is thus not surprising that mining has a reputation of being a dangerous industry and there is a compelling need for risk management and accident prevention, especially in underground environments.

[1] Nexsys is a trademark of the CSIRO.

Mine monitoring and data communications systems are increasingly becoming more complex and diverse. Multiple proprietary systems are used for mine environment, equipment and infrastructure monitoring, transmitting over 20 000 pieces of data into control rooms in a few seconds [3]. The amount and variety of available data is overwhelming for mine control room operators to analyse rapidly, especially in emergency situations when speed is of the essence.

In many mine-related incidents over recent years, predictive data was available but often too ambiguous, incomplete or distributed across too great a number of disparate proprietary systems to be effectively used [3].

In response to these issues facing the mining industry, the Nexsys™ Realtime Risk Management System has been developed to provide a Decision Support System for the mining industry. Nexsys™, within its risk management analysis system, is capable of integrating and interpreting proprietary system data to provide real-time safety-critical hazard analysis, with reference to relevant industry standards.

The Nexsys™ development, funded by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) Exploration and Mining Division, Japan Coal Energy Center (JCoal) and the Australian Coal Association Research Program (ACARP), is currently at a pre-commercial stage.

2. THE ROLE OF NEXSYS™

Nexsys™ is a risk and hazard management tool developed initially for underground coal mines, with a high potential for implementation in a range of surface mining and non-mining related industries.

Nexsys™ detects potentially hazardous combinations of mine conditions through monitoring real-time critical data from its sources. Nexsys™ acts as a mine-wide reporting system providing the ability to record and report current or potential hazards in real-time [3]. The system draws together a range of important information from numerous data sources and effectively reduces the variability and uncertainty in data interpretation. For example, Nexsys™ provides a multilevel mine plan view showing the locations of sensors, personnel and equipment, which assures that safety equipment can be located quickly and effectively in an emergency situation [3].

Nexsys™ differs from other existing mining monitoring systems which, in general, monitor only particular aspects of a mine and provide relatively simple data analysis and decision support capabilities. Nexsys™ gathers information about the status and health of the entire mine by integrating data from various separate systems and adding an interpretive and preventative analytical layer.

The interpretive nature of Nexsys™ provides a solution to the abundance of false alarms that occur in mining systems, allowing mine control room operators to focus on the information critical to mine safety.

3. ARCHITECTURE

The Nexsys™ system has been developed using modern C# programming methods under the Microsoft .Net Framework™. The system consists of a client, server and database management system (SQL Server 2005), each of which can reside on separate machines located at various sites around the world. The system is generally located in a mine control room., The client however, which communicates with the server using either Web Services or .Net Remoting, can effectively be located anywhere on the Internet. Furthermore, Nexsys™ has a read-only web-based client that can be accessed from any Internet browser, including those on PDAs. This provides the capability to monitor the mine from anywhere in the world even in the absence of the full Nexsys™ client software (Figure 1).

A typical Nexsys™ installation at an underground coal mine site might include a Nexsys server in the mine control room, connected to and importing data from various proprietary mine computer systems and sensors. Nexsys™ clients might be located in the mine control room, in offices, on the laptops of various personnel on and off site, and on PDAs with web-based Nexsys™ clients. Nexsys™ could also be connected to a personnel and equipment locating system, which transmits location back to the Nexsys™ server and hence the Nexsys™ clients.

4. FEATURES

Risk Profile

One of the key features of Nexsys™ that sets it apart from other available technologies is the implementation of a novel risk profiling matrix. This matrix, based on likelihood and consequence, is dynamically populated by automated rules that monitor the status of the controls in the mine incorporated into a mine's Trigger Action Response Plan (TARP).

The Nexsys™ Risk Profile (Figure 2), based on a standard mine risk profile template, allows a particular risk profile to be displayed in real-time on its likelihood/consequence diagram with a user-enabled view of the change in risk over a specified time period. The display varies from green through amber to red with risk increases for example, identified and tracked using a dot

point identifier travelling from the green to the red section of the graph.

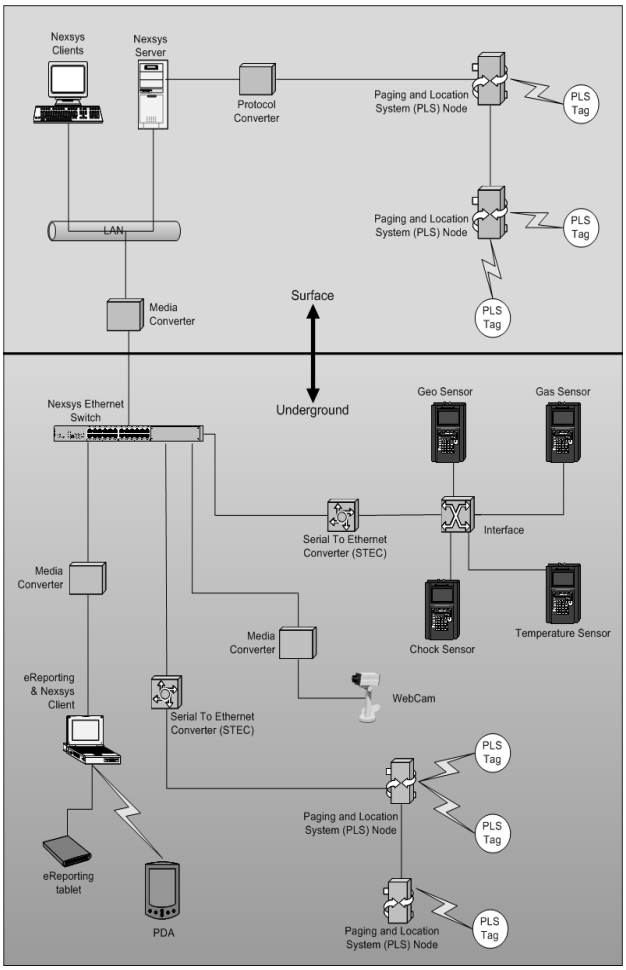

Figure 1. A typical Nexsys™ topology in an underground coal mine.

The greyscale image in Figure 2 is a representation of the likelihood-consequence matrix ranging from green in the bottom-left corner through amber in the centre diagonal to red in the top-right corner. The profile shows three risks, two of which are constant in the specified history period, and a third which has moved in the directions depicted by the lines shown on the image (the likelihood and consequence of the risk have decreased slightly, and then these have both greatly increased).

A multitude of rules can be used to generate the overall risk profile. For example, a rule that increases the likelihood of a fire when the CO concentration increases beyond a certain value within the mine can be applied.

In this case, the risk identifier would move to the right on the matrix display and hence towards the red section of the graph. Another rule could reduce the likelihood of a fire if the measurement of CO concentration drops below a specified level. In this case the risk identifier would move back towards the green section of the graph. It must be emphasised that not all high risk assessments on the likelihood-consequence matrix result in an incident as the actual state at the mine depends on variety of conditions and the actual hazard must be ultimately determined by a mine control operator. This is clearly illustrated when risk increases and decreases in quick succession without incident when a sensor detects CO as a mine vehicle travels past the sensor emitting CO in exhaust.

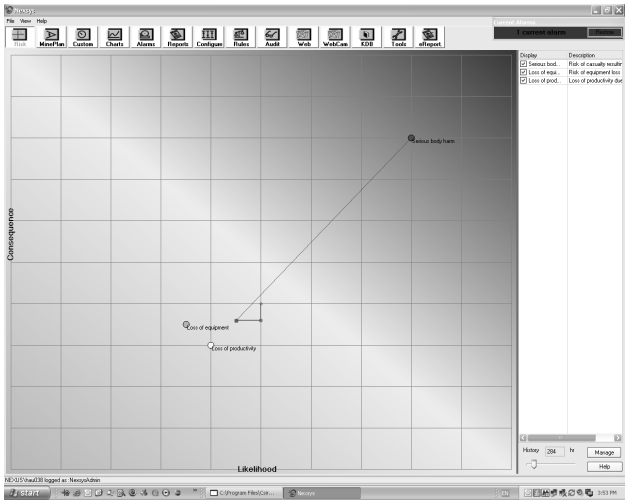

Figure 2. The Nexsys™ Risk Profile displaying two static risks and one changing risk.

The rules that trigger movement in the risk profile are discussed further under Rule Engine and Alarms.

Data Integration

Nexsys™ also provides solutions to managing a large volume of mine site sensor data. This overwhelming amount of often ambiguous, incomplete and incompatible data comes from a range of proprietary systems and must be quickly processed and responded to by mine control room operators. Lack of data fusion and interpretation in current monitoring systems leads to a large number of false and low priority alarms, which subsequently lead to an operator's inability to detect and respond to true and high priority alarms.

The Nexsys™ system provides its integrated data view by importing data from proprietary mining systems, or directly from sensors themselves, into one database using customised data connectors. Significantly, the individual mine sites can determine which data sources are critical from any of the monitoring systems in use and hence are relevant to import and be shown in Nexsys™.

Data Views

The system provides a variety of user interface options. For example, a single view can be utilised for comparison and display of data in multiple formats, which can be adapted to the most appropriate form to support risk

management decision-making at a particular mine. While the current system displays past and present data, a predictive data analysis feature is under active development (see section on Anomaly Detection).

A variety of displays, including charts, dials and gauges, updated in real-time is provided by the Nexsys™ system. Nexsys™ provides a web-cam link for live-mine viewing. Data sources can be selected by name or location on a 2-dimensional or 3-dimensional mine plan. This mine plan is automatically updated from the latest surveyor drawing (Autocad/dxf) file stored on the server, a feature which is not available in any real-time Supervisory Control And Data Acquisition (SCADA) system used currently for mine control. Various layers of the mine plan can be turned on/off to show/hide mine details as required. Sensor information from SCADA systems connected to the Nexsys™ system can be shown on this view and graphed upon selection. The Nexsys™ mine plan view can also be used to view the last known location of personnel and equipment when connected to a location monitoring system.

Figures 3 and 4 show the Nexsys™ 2-dimensional and 3-dimensional mine plan views, respectively.

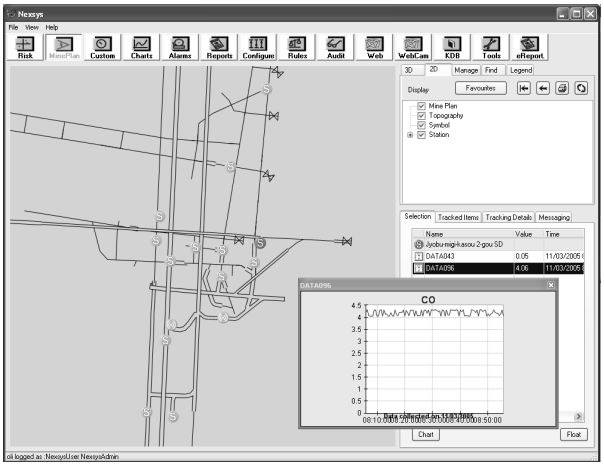

Figure 3. The Nexsys™ 2-dimensional mine plan view.

Nexsys™ also has a reporting capability using Crystal Reports that allows selected data to be formatted in a reader-friendly manner.

Rule Engine and Alarms

As aforementioned, Nexsys™ provides alarms generated by mine-specific rules that analyse the data and trigger prescribed responses to the state of this data. The rule engine provides decision support by using Boolean logic to determine a set of actions to take in response to a particular sequence of events determined by the state of the data in the database. This data includes gas, ventilation, geotechnical and personnel, vehicle and equipment location information. When an alarm is raised, appropriate diagnostic guidance and trigger action response plans can be forwarded to the appropriate personnel by way of email/SMS, messaging personnel using a mine messaging system, or updating the Nexsys™ Risk Profile.

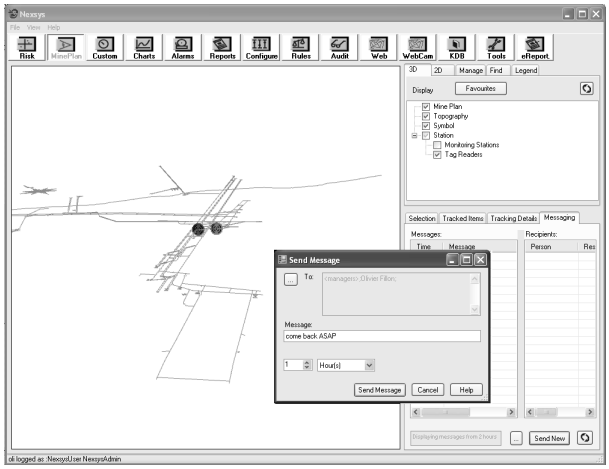

Figure 4. The Nexsys™ 3-dimensional mine plan view.

The rule engine constantly polls the available data to check if conditions are met. For example, if a particular gas sensor reading is above a specified level then the system will raise an alarm and send an evacuation message to miners carrying paging devices in a designated area.

During the trial Nexsys™ mine installations (see section Installations), mines have used up to 400 different rules (Figure 5 shows some rules used in the trial installations) monitoring different gas concentrations, fans and other variables.

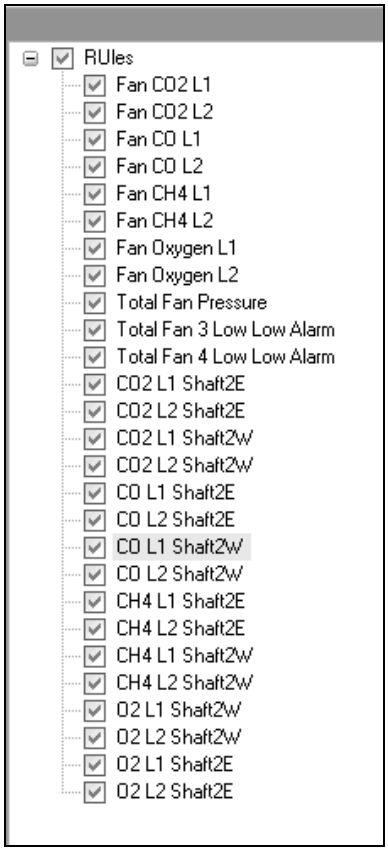

Figure 5. An example set of Nexsys™ rules used to monitor gas concentrations, fans, etc.

Each rule has a condition that must be met to trigger a particular response (using the format IF condition holds THEN take actions). Nexsys™ provides a simple wizard for creating simple IF-THEN rules while IF-THEN-ELSE rules (with alternate actions if a condition is not met) can be created using the Advanced Rule Editor. Figure 6 shows the simple Nexsys™ Rule Wizard.

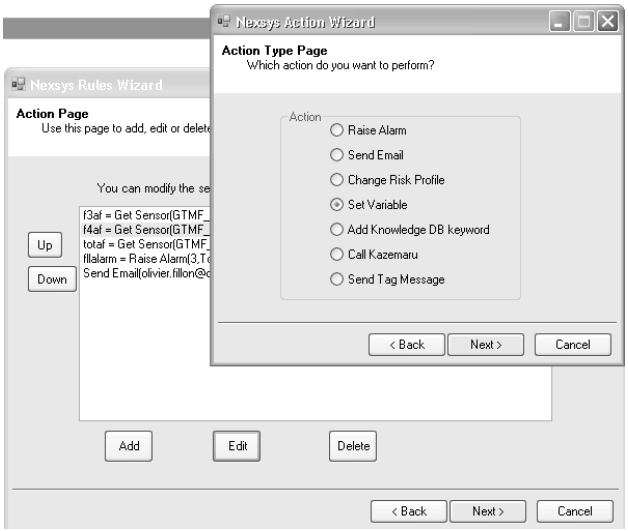

Figure 6. The Nexsys™ Rule Wizard.

Figure 7 shows an example Nexsys™ rule that checks whether the Total Fan Pressure is too high, and, if that is the case, triggers an alarm and notifies the appropriate personnel with the relevant sensor values. The sensor values in the *Then* clause are written to variables, which are then printed out in the alarm and the sent email.

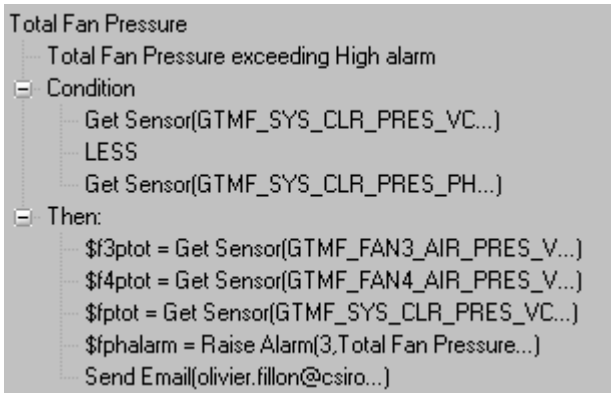

Figure 7. An example Nexsys™ rule for Total Fan Pressure levels.

Alarms are assigned a level of importance (ranging from 0 for an alert to 4 for critical) and appear at the corner of the Nexsys™ screen at all times; this alarms window can be minimised but at all times states how many alarms exist, and changes colour from green to red when an alarm is raised. This allows users to always be aware of existing alarms while they are working on other things.

Anomaly Detection

Another unique feature of Nexsys™ is a predictive analysis and anomaly detection component, which uses past mine monitoring data to predict future hazards and evaluate associated risk. This would enable pre-emptive and preventative actions to be initiated before an event reaches critical state. Furthermore, as many false alarms are triggered in non-dangerous situations, anomaly detection can be used to indicate whether a certain state of events is normal or anomalous and hence whether an alarm is likely to be false or true.

The results of the predictive analysis and anomaly detection component are used to trigger alarms and modify the Nexsys™ Risk Profile. The threshold that determines an anomaly can be changed by the user when setting up rules to trigger alarms.

Security

Nexsys™ security includes authentication, using Windows Groups, and an audit log. Several authentication levels can be set, as per mine directives, determining which groups can access particular Nexsys™ components. A typical setup includes an Administrator and a User group but may include a Super Administrator group, with privileges such as clearing the audit log.

5. INSTALLATIONS

The Nexsys™ system was originally developed for the purpose of coal mine safety and as such has been successfully demonstrated in 2005/2006 at three mine sites: Beltana and Grasstree Longwall Coal Mines in Australia and the Kushiro Longwall Coal Mine in Japan.

Two field trials were conducted at the Grasstree Mine in 2005. For both trials, Nexsys™ was successfully connected to CITECT's SCADA system in use, as well as to a personnel and equipment location tracking system. Rules were created to trigger alarms and contact the appropriate personnel if carbon monoxide, carbon dioxide, oxygen and methane levels were unsafe or fans were not working properly.

For the Beltana field trial in 2005, Nexsys™ was also successfully connected to a CITECT system. Rules were created to trigger alarms and contact the appropriate personnel when events occurred, such as, borehole water level too high, borehole pump not working, methane gas level in the longwall too high, or shearer approaching.

Two field trials were conducted at the Kushiro Coal Mine in 2005 and 2006. For both of the Kushiro installations, Nexsys™ was successfully connected to the SCADA system, the mine's proprietary ventilation analysis software as well as a personnel and equipment location tracking system. Four hundred rules were created to trigger alarms when particular concentrations of carbon monoxide and methane occurred.

Through the field trials many valid experiences were gained and, as a result, Nexsys™ was developed into a more robust, refined, user-friendly system. The Nexsys™ servers and clients installed at these mine sites continue to run today.

Since these installations many other potential applications of Nexsys™ have arisen which are currently being explored.

6. CONCLUSIONS

As mine safety is an area of critical concern to the mining industry, the Nexsys™ real-time risk profiling and remote monitoring of multiple sites has the potential to aid significantly in the improvement of safety performance and hazard management across the international mining community.

10. REFERENCES

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