Nexsys™: A Realtime Risk Management System for Mine Safety

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Abstract

Effective risk management is essential for mine safety but is difficult to achieve on an ad-hoc basis. Newly developed by CSIRO, the Nexsys™[1] Real-Time Risk Management decision support system provides continuous monitoring, evaluation and reporting of mining conditions, supports operators in the decision making process and allows rapid communication with mine site personnel.

Nexsys™ integrates abundant mine data from various proprietary systems and independent sensors to support safety-critical hazard analysis in real-time. A key feature of Nexsys™ is a novel risk profiling matrix, dynamically populated by automated rules based on the mine's Trigger Action Response Plans.

The Nexsys™ architecture comprises a server, a client (that can be located worldwide), and a web-based read-only client that can be accessed from any web-enabled device such as a PDA. The interface provides safety-related warnings and multi-dimensional displays of sensors, equipment and personnel location embedded within the mine plan.

The paper highlights the potential for Nexsys™ to significantly enhance safety performance and hazard management in mining. It also discusses key learnings gained through successful pilot deployments at longwall operations at Beltana and Grasstree (Australia) and the Kushiro coal mine (Japan).

[1] Nexsys™ is a trademark of the CSIRO.

Introduction

Risk management plays a vital role in mine safety. Standing in the way of effective risk management is the use of multiple incompatible proprietary systems and the excessive amount of data available from these systems to mine control room operators to monitor safety effectively. Over twenty thousand pieces of data can be transmitted into a mine control room in a matter of seconds (Einicke and Rowan, 2005). Effective information management is critical prior to and during emergency situations; many incident evaluations have shown the existence of predictive data but a lack of integration and interpretation has inhibited the delivery of vital information to mine site personnel (Einicke and Rowan, 2005). If this data were properly interpreted, many of these incidents could have been prevented or their consequences reduced (Addinell, Rowan and Matsuyama, 2005).

The need for a high level integrated mine risk management system triggered the development of the Nexsys™ Real-Time Risk Management decision support system. Jointly developed by CSIRO and the Japan Coal Energy Center (JCOAL), Nexsys™ offers mine operators the ability to process vast arrays of data to assess the status of mine safety in real time. By integrating data from a range of proprietary systems within a single concise system, Nexsys™ provides real-time safety-critical hazard analysis, enabling operators to make informed decisions in safety-related areas. In comparison to other mine monitoring systems, which typically monitor only particular aspects of a mine's health and provide relatively simple data analysis and decision support, Nexsys™ draws information on the condition of the entire mine and adds an interpretative and preventative analytical layer together with a greatly enhanced data analysis capability (Haustein et al., 2008). Thus Nexsys™ is a truly mine-wide hazard reporting system that monitors real-time critical data to detect potentially hazardous mine conditions. Through its data analysis capability over a multitude of domains, Nexsys™ is designed to reduce the uncertainty and variability in the interpretation of this data. Nexsys™ was initially developed for the underground coal mining industry but has the potential to be used in a wide range of industries.

Architecture

The Nexsys™ system includes a central server connected to a client, typically located on a separate machine, which can be remotely located with access via the internet. Generally the server resides in the mine control room and can be connected to various other systems, such as Citect's Supervisory Control and Data Acquisition (SCADA) system, while the clients can be located anywhere worldwide. Nexsys™ features a web-based read-only client that can be accessed over the internet from an internet browser via any web-enabled device, including PDA. The general architecture of Nexsys™ is shown in Figure 1.

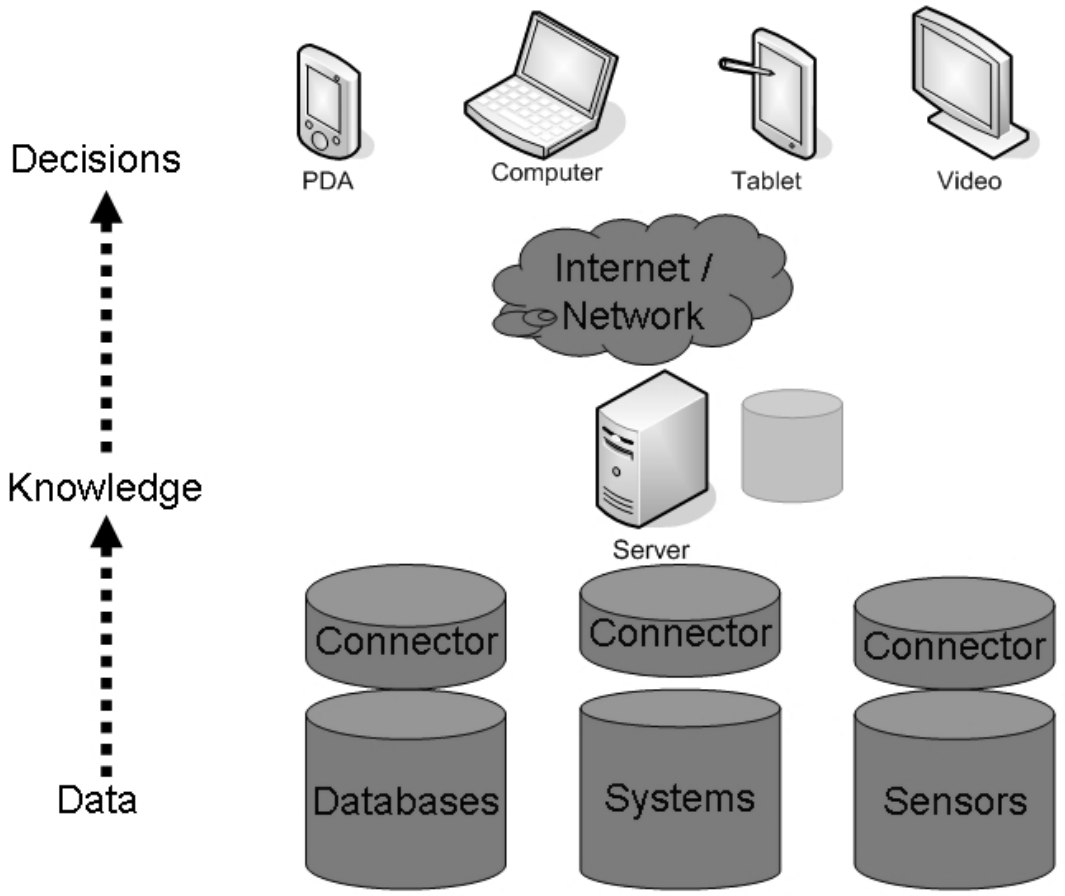


Figure 1. The basic Nexsys™ Architecture.

Features

A key feature of Nexsys™ is the Real-Time Risk Profile which displays risk on a standard mine likelihood-consequence template. The mine risk status is updated by automated rules with the change in risk displayed over a particular time period on the colour coded screen: from green, indicating low risk of incident through yellow to red, indicating a high risk of incident (Figure 2). The risk levels are formed based on the mine Trigger Action Response Plans, which follow the automated rules. For example, risk level is increased with rising methane concentration levels, as detected by a sensor. The relationship between risk level, hazards and incidents is subject to sensor location, activity undertaken in its vicinity and other variables. For instance, raised carbon monoxide levels, when a vehicle drives past a carbon monoxide sensor, would increase the level of incident risk; however, as soon as the vehicle has past the sensor, the carbon monoxide levels would decrease rapidly reducing risk to low likelihood/consequence status.

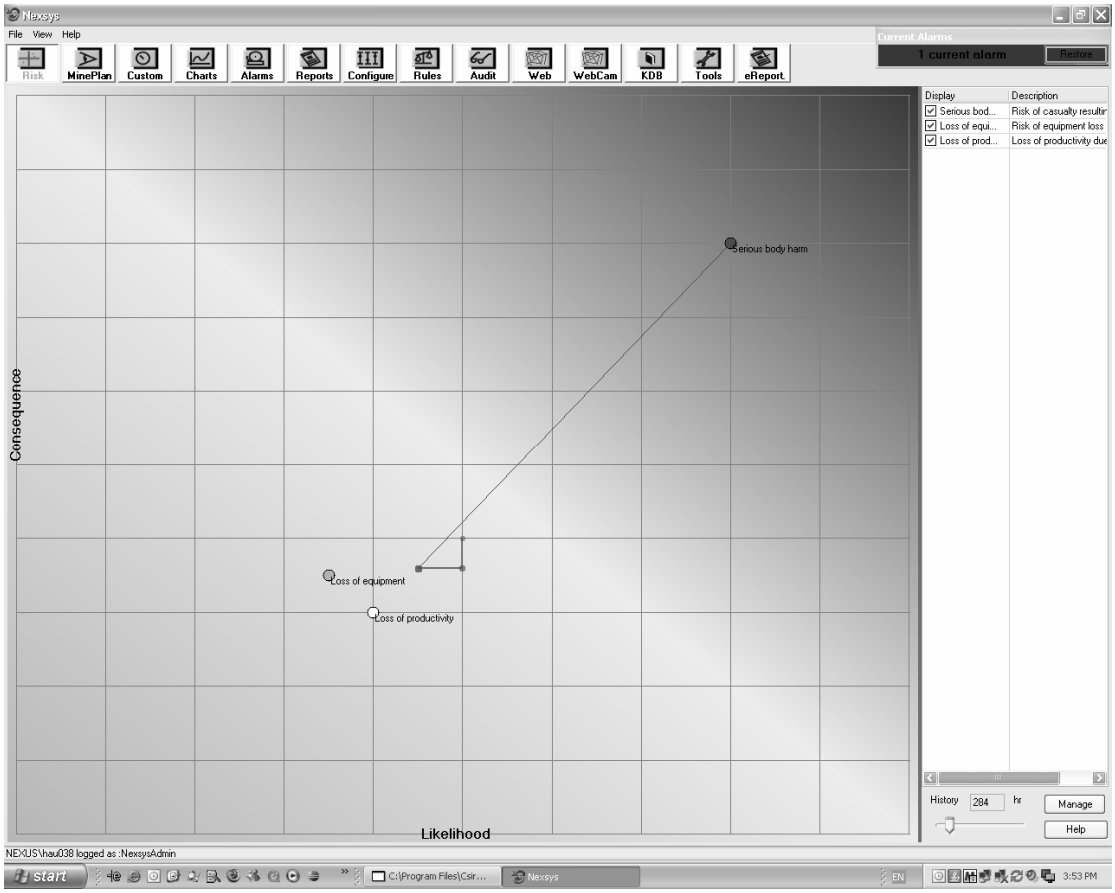


Figure 2. The Nexsys™ Risk Profile. The lower left-hand corner of the graph is represented in green, merging through yellow in the centre to the right-hand upper corner of the graph that is represented in red.

To provide real-time risk assessment, Nexsys™ is equipped with data integration capability, which is paramount in overcoming the large number of false and low priority alarms existing in current monitoring systems, thus allowing mine control room operators to focus on high priority alarms. Nexsys™ draws data into its database from a variety of sources using 'Data Connectors' that interface with various proprietary systems, sensors and personnel locating and messaging systems. Real-time data analysis and feedback to the operator allow for rapid response to emergency situations including communication with personnel in time-critical situations.

A variety of displays are tailored to enhance the operator's ability to quickly process information. Two and three-dimensional mine plan views (Figures 3 and 4), network camera views of critical sections of the mine (Figure 5), charts, dials and gauges (Figure 6), reports (Figure 7) and predictive data analysis (Figures 8, 9 and 10) are just few of the range of views available. The mine plan views allow users to turn on and off various layers of the mine plan, select data by name or location and display or graph the information for ease of understanding. The mine plan is automatically updated from the latest surveyor drawing (an Autocad file), a feature that is not currently available in any other mine monitoring system. From the safety point of view, the last known location of personnel and equipment is essential, especially during emergency evacuation; Nexsys™ has the ability to interface with man/equipment tracking systems and to provide this information to relevant personnel.

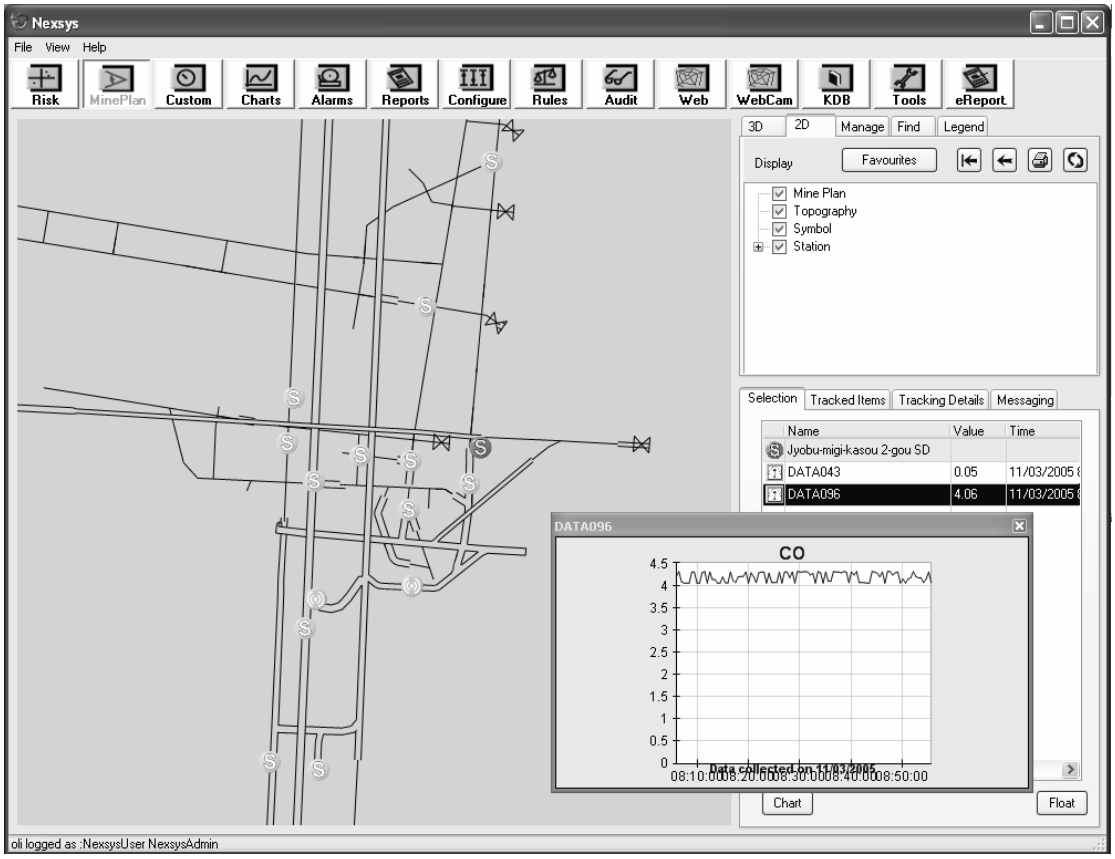


Figure 3. The Nexsys™ 2-dimensional mine plan view.

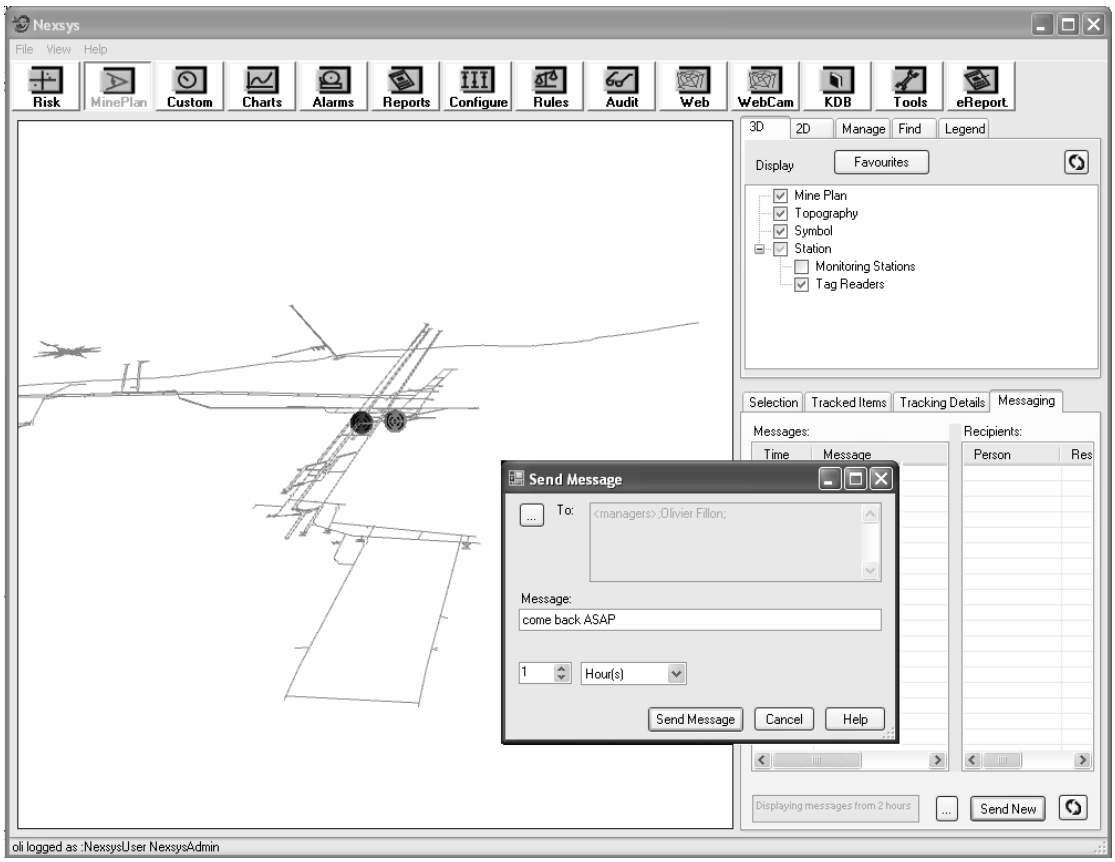


Figure 4. The Nexsys™ 3-dimensional mine plan view.

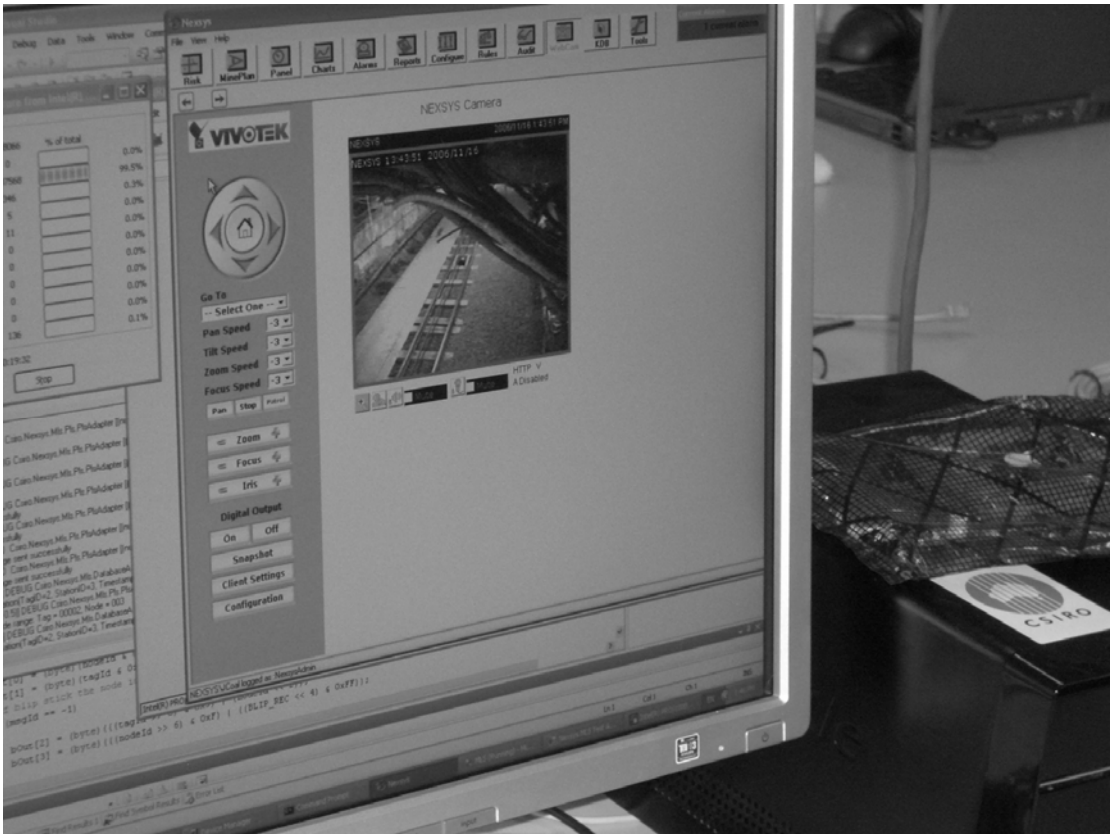


Figure 5. The Nexsys™ web-cam view.

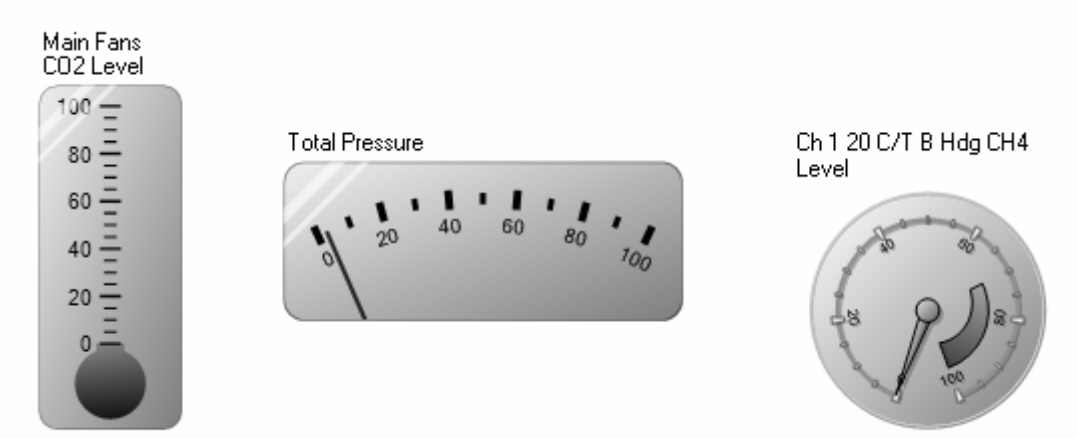
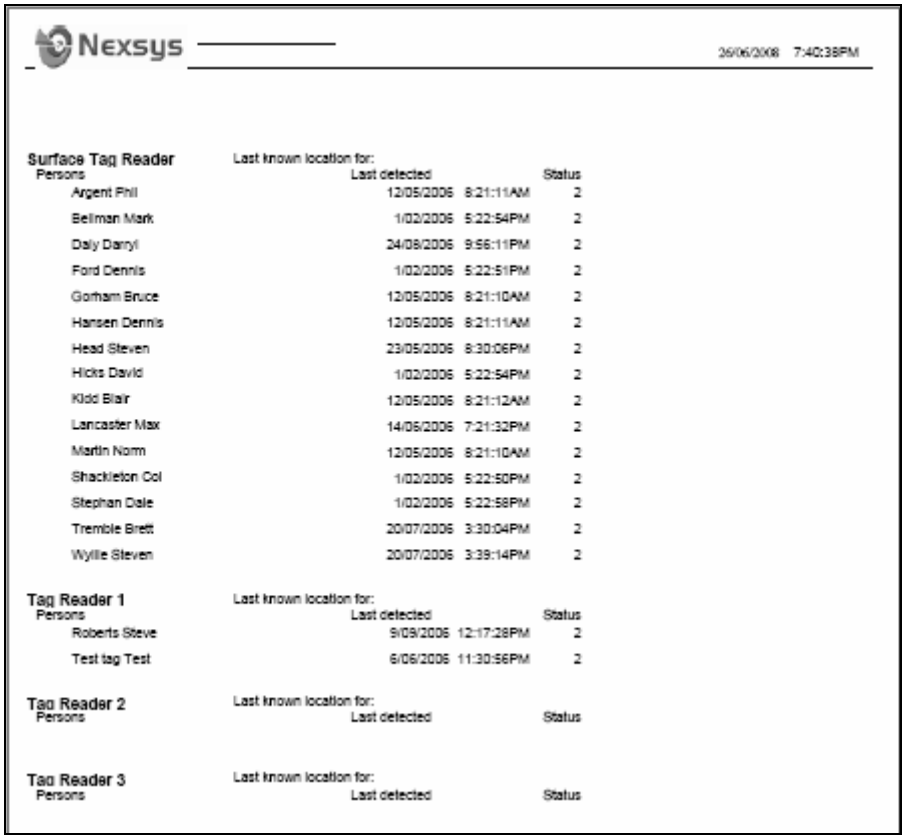


Figure 6. Various dials and gauges that can be used in Nexsys™ for data display.



Nexsys

26/06/2008 7:40:38PM

Surface Tag Reader

Persons	Last known location for: Last detected	Status
Argent Phil	12/05/2006 8:21:11AM	2
Bellman Mark	1/02/2006 5:22:54PM	2
Daly Darryl	24/08/2006 9:56:11PM	2
Ford Dennis	1/02/2006 5:22:51PM	2
Gorham Bruce	12/05/2006 8:21:10AM	2
Hansen Dennis	12/05/2006 8:21:11AM	2
Head Steven	23/05/2006 8:30:06PM	2
Hicks David	1/02/2006 5:22:54PM	2
Kidd Blair	12/05/2006 8:21:12AM	2
Lancaster Max	14/06/2006 7:21:32PM	2
Martin Norm	12/05/2006 8:21:10AM	2
Shackleton Col	1/02/2006 5:22:50PM	2
Stephan Dale	1/02/2006 5:22:58PM	2
Tremble Brett	20/07/2006 3:30:04PM	2
Wylie Steven	20/07/2006 3:39:14PM	2

Tag Reader 1

Persons	Last known location for: Last detected	Status
Roberts Steve	9/09/2006 12:17:28PM	2
Test tag Test	6/06/2006 11:30:56PM	2

Tag Reader 2

Persons	Last known location for: Last detected	Status

Tag Reader 3

Persons	Last known location for: Last detected	Status

Figure 7. A sample Nexsys™ report.

Data analysis is undertaken using the Nexsys™ rule engine, which examines the mine status against a set of criteria critical to mine health and safety. The rule engine constantly polls the available data to determine if specific rule conditions are met and, using conditional logic, to trigger an automatic response if necessary.

Two types of Nexsys™ rules can be created: simple rules, taking the format ‘if condition(s) met, then take action(s)’, and advanced rules, taking the format ‘if condition(s) met, then take action(s), otherwise take alternative action(s)’. To create Nexsys™ rules, a simple rule wizard and an advanced rule editor are provided. Up to 400 rules per mine were used during testing of the Nexsys™ system at various mine sites (see Installations section), however the number of rules that can be created is limited only by computing resources.

Data analysed may include gas levels, ventilation and geotechnical conditions or personnel and equipment location. Prescribed responses include triggering alarms, emails or SMS, messaging mine personnel using a mine messaging system and updating the Nexsys™ Risk Profile. For example, detection of methane levels higher than a set limit value would trigger an alarm, notify appropriate personnel and provide the appropriate Trigger Action Response Plan.

An important aspect of condition monitoring in underground coal mines is the evaluation of the concentration of combustible gas mixture (methane, carbon monoxide, hydrogen) and oxygen concentration level, which might lead to highly dangerous conditions portrayed by the well-known Coward Triangle (Figure 8). The likelihood-consequence risk profiling relies on such data contained within the mine monitoring systems to alert the operator of the likelihood that the gas-oxygen mixture will approach hazardous conditions.

To complement the existing risk profiling component of the Nexsys™ system an anomaly detection module is under development, which, on one hand, incorporates historical data to predict and evaluate current and future risks and hazards (Figure 9) and, on the other hand, employs a variable threshold limit (band) to eliminate false and detect true alarms (Figure 10).

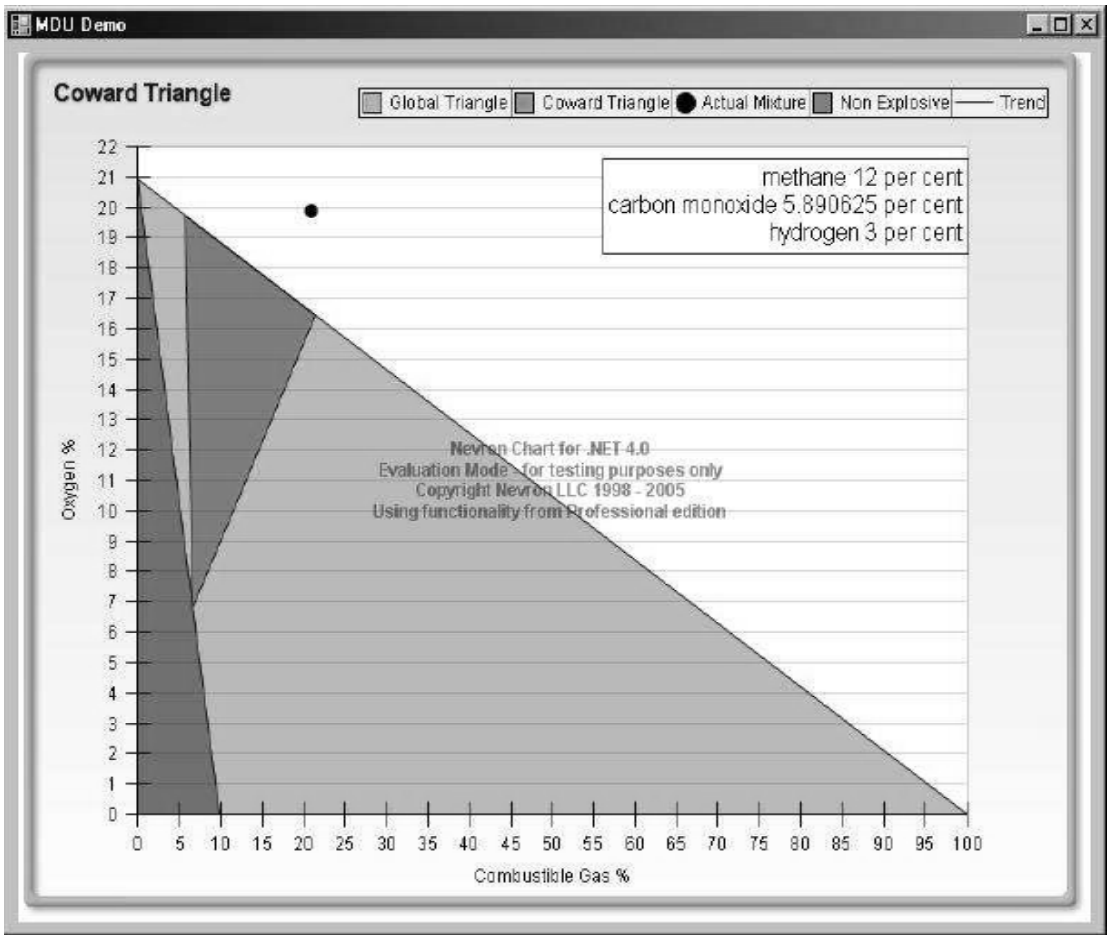


Figure 8. The Coward Triangle.

The predictive nature of this analysis would lead to the reduction/elimination of incidents through pre-emptive, preventative actions.

Figure 9 demonstrates how anomaly detection can be used to detect false alarms. Sensor readings, are shown by the disparate values, with predicted (and hence normal) sensor values shown by the continuous line. The horizontal line demonstrates where, if used, a fixed threshold representing unsafe sensor readings would be defined. Current mine monitoring systems may trigger false alarms if cyclical baselines are ignored and fixed thresholds are used, as what is considered normal gas levels do not remain constant throughout the day and often follow a cyclical pattern. This is because these gas levels are affected by various "normal" mine events, for example carbon monoxide sensor readings would rise as a vehicle passes a sensor. As the baselines of what are normal gas concentrations change throughout the day, so too does the concentration that indicates a high risk of incident. Figure 9 demonstrates four sensor readings that exceed the chosen fixed threshold and therefore would trigger an alarm in current mining monitoring systems. Even though these levels do not greatly exceed what is considered normal at the time of day shown by the cyclical or moving threshold, these values would still trigger false alarms. The number of false alarms often would prevent the mine control room operators from responding efficiently to true alarms. The Nexsys™ anomaly detection component attempts to quantify the anomalous events (in terms of risk) and raise an alarm only if the conditions warrant it. Figure 10 demonstrates the detection of true alarms signals, triggered by anomalous sensor readings that do not lie close to the predicted values.

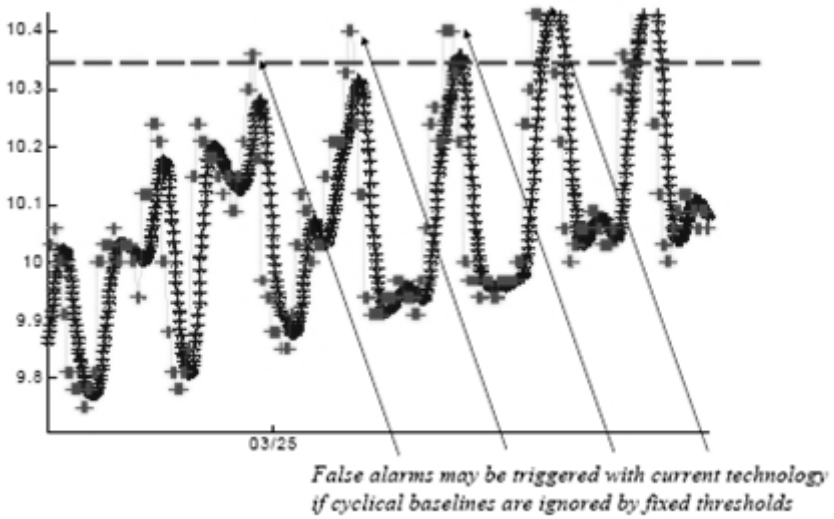


Figure 9. An example chart generated by the Nexsys™ anomaly detection component showing predicted (normal) sensor readings (the continuous line) and actual sensor readings (the disparate values).

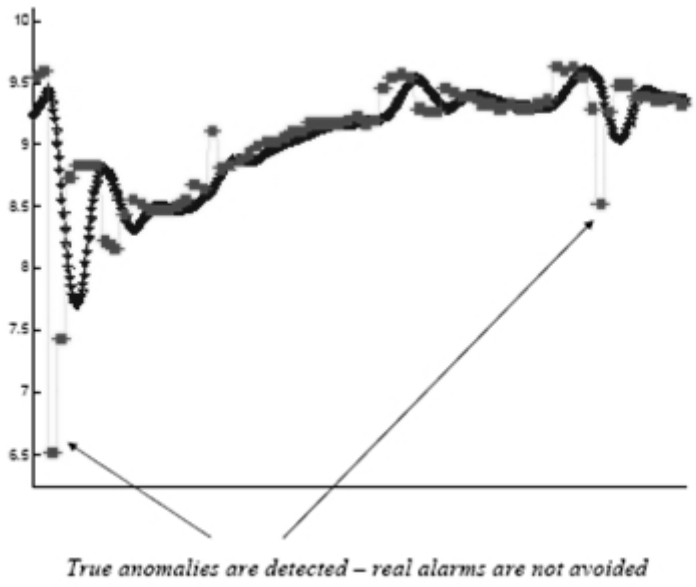


Figure 10. A chart generated by the Nexsys™ anomaly detection component showing predicted (normal) sensor readings (the continuous line) and actual sensor readings (the disparate values).

Nexsys™ has been developed to implement appropriate security levels, requiring user authentication and restricting system access to specified users.

Nexsys™ Field Testing

The research prototype of the Nexsys™ system was tested at three different longwall coal mines: the Grasstree mine in Queensland, Beltana mine in New South Wales and Kushiro mine in Hokkaido, Japan.

Two field trials were conducted at the Grasstree mine in 2005 where Nexsys™ was connected to Citect's SCADA system and a CSIRO-developed Location and Monitoring for Personal Safety (LAMPS) system developed for personnel location and communications. The Nexsys™ system is able to send a signal to miners through LAMPS, notifying them to contact the mine control room when required. Rules were created to detect unsafe carbon monoxide, carbon dioxide, oxygen and methane levels, and to detect if the fans were not working properly. Detection of data exceeding specified threshold limits triggered alarms and emails sent to the appropriate personnel.

The field trial installation at the Beltana mine was conducted in 2005 and Nexsys™ was connected to Citect's SCADA system. Rules were created to detect if the borehole water level was too high, the borehole pump was not working, the methane level in the longwall was too high or the coal shearer was approaching. These events would trigger alarms and emails to appropriate personnel.

Two field trial installations were conducted at the Kushiro mine in 2005 and 2006. Nexsys™ was connected to the SCADA system and proprietary ventilation analysis software Kazemaru. In 2006 Nexsys™ was connected to a Hitachi man locating system and, in 2006, Nexsys™ was connected to a CSIRO-developed man locating and messaging system, the Paging and Location System (PLS). As well as giving location, the PLS allowed for sending messages to miners and for miners to respond with one of three responses ('yes', 'no' and 'ok'). Four hundred rules were created detecting unsafe levels of carbon monoxide and methane as well as ventilation system malfunctions. These rules triggered alarms under such circumstances.

The Grasstree, Beltana and Kushiro Nexsys™ systems continue to run today and provide invaluable data for further development of the system.

Conclusions

The Nexsys™ Realtime Risk Management decision support system is able to improve mine safety through its continuous monitoring of the state of a mine, integrating critical mine data from various systems and sensors and notifying the appropriate personnel using a variety of decision support tools. Due to the critical importance of effective risk management in mine safety and the lack of similar systems, Nexsys™ has a great potential to contribute to safety improvement in the international mining community. Future directions for Nexsys™ include development and application in underground (coal and metalliferous) and surface mines as well as in non-mining domains.

References

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