The mining industry is recognized as one of the most important industries the world over as it goes a long way in meeting the coal and other mineral requirements of a country and provides employment to a large number of people. But this industry, because of the nature of the work, is highly hazardous due to various types of accidents, which take a heavy toll on human life, inflict injuries to several workers and damage mine properties every year. Rigorous surveys and investigations carried out by different researchers have confirmed that most of these accidents can be warded off by taking suitable precautions in real-time, based on the regular and systematic monitoring of the prevailing underground mining environment, geological features and mechanical soundness—as well as the integrity of performance of mining machinery and equipment.

Sensing the need of the hour the authors have come up with a book entitled *Sensing and Monitoring Technologies for Mines and Hazardous Areas*, which will act as a best-practice resource in the mining industry. It will be highly beneficial to the industry as it presents a variety of details on the latest sensing and monitoring technologies that are using innovative ideas, along with details on digital mining and cloud computing, which are essential for improving the safety and productivity of this industry. The book contains seven chapters covering a wide range of recent developments in these areas for use in the mining industry and in other hazardous areas.

**Chapter 1—Slope Failure Mechanism and Monitoring Techniques**: Opencast mining operations involve the removal of huge quantities of overburden. A substantial increase in the accumulation of waste materials in recent years and the nonavailability of enough space for their disposal leaves no alternative but to increase the height of dumps, giving rise to the danger of dump failure. In the case of large open-pit mines, steep slopes are prone to failure. These failures lead to a loss of valuable human lives as well as damage to mining machinery. Different technologies are available for slope monitoring. After studying the features and limitations of the existing slope monitoring systems, it was felt...
that there was a necessity to develop a reliable slope stability monitoring and prediction system by using a solar power-based, long-range wireless sensor network for the continuous monitoring of different prevailing parameters of slope stability. To meet this requirement, a slope failure monitoring and prediction system has been developed by the authors using a wireless sensor network. The system continuously monitors various parameters pertaining to slope stability and provides early warning of impending slope failure on the basis of multi-parameter prediction models. Besides mining, this technology is applicable for monitoring the stability of dam slopes and steep slopes along railway tracks and roads in hilly terrains. The chapter describes the details of the slope stability mechanism, parameters effecting slope failure and its triggering aspects, monitoring systems, predictive software, laboratory experiments for calibrating geosensors and field installation of the developed system.

Chapter 2—Mine Transport Surveillance and Production Management System: Mine transport surveillance and production management system has been designed with the aim of checking for the overloading of minerals on trucks or dumpers and the efficient removal of minerals from a mine site, while at the same time stopping the illicit transportation of minerals through unauthorized routes. The system consists of five modules: the weighbridge automation module for the unmanned check of mineral overloading on trucks or dumpers; the vehicle tracking and production monitoring module for keeping a continuous watch on the vehicles on transportation routes, and the monitoring of production, as well as providing advice on the optimum use of shovels, dumpers and other auxiliary equipment by minimizing their idling time; close circuit television cameras for keeping the surroundings under constant surveillance, particularly to watch vehicles carrying minerals; a periphery surveillance module for detecting the intrusion of vehicles that have the intention to illegally transport minerals through unauthorized routes; and a centralized monitoring station for overseeing all the activities of transport surveillance and production monitoring. This system would definitely prove to be a boon to the mining industry as it is quite effective in preventing financial loss due to mineral theft, while at the same time improving the efficiency of the smooth dispatch of minerals through the optimum use of shovels and dumpers.

Chapter 3—Gas Sensors for Underground Mines and Hazardous Areas: Some strata gases that get mixed with underground mine atmospheres are highly poisonous and a few are dangerously flammable. Various gases are also formed in underground mines due to chemical reactions such as the spontaneous heating of coal, etc. The concentration of mine gases found at any time and location may vary due to different factors like diffusion, turbulent dispersion and leakage in subsurface ventilation systems. Therefore, it is necessary to deploy sensors to monitor and measure toxic and flammable gas concentration levels in
the subsurface atmosphere for the safety of underground miners as well as mines themselves. Each sensor has its own advantages and limitations. Some sensors are better for sensing toxic gases, whereas others are suitable for combustible gas detection. This chapter presents the principles and application of different types of gas sensors, procedures for sensor deployment and the calibration and interpretation of sensor data.

**Chapter 4—Local Methane Detection and Power Cut-Off System:** Local methane detection and power cut-off system for underground mines have been designed to accomplish the continuous monitoring of methane gas concentration. They consist of subunits, namely an intake fan, an infrared methane sensor, a loud audio alarm generator, a visual display screen, an auto power cut-off relay, a detachable battery, a remote read out facility and a micro-controller. The mining industry will benefit highly from this development as it prevents mine disasters caused by methane explosions through cutting off the power supply when methane concentration exceeds the permissible limit, and at the same time triggering alarms that help in the evacuation of miners and machinery from the danger zone, which results in the saving of valuable human lives as well as mine property.

**Chapter 5—Integrated Mine Environment and Strata Condition Monitoring System:** Underground coal mines are well recognized as hazardous areas that are prone to accidents caused by roof fall, and the collapse of gallery sides, gas poisoning, gas and coal dust explosions, etc. Besides these hazards, the working environment inside a mine often becomes uncomfortable due to a deficiency of oxygen; the sudden appearance of toxic, inflammable and unpleasant gases; and an increase in temperature and excess humidity. To cope with these problems, the mining industry is in need of suitable sensors that assess different underground situations and give warning of impending dangers, and that allow for the taking of proactive actions. This chapter contains details about the integrated environment and strata monitoring system developed by the authors of this book. This system is capable of monitoring seven gases (methane, carbon monoxide, carbon dioxide, oxygen, nitrogen dioxide, sulfur dioxide, and hydrogen sulfide) and other environmental parameters like air velocity, temperature and humidity. It can also be used for monitoring three strata parameters (the load of the roof at a particular point, the convergence of the roof and the pressure on pillars) and different micro-seismic events that generally occur in mines mainly due to blasting and roof fracturing. The uniqueness of this system is that it accommodates 14 different sensors for monitoring respective parameters.

**Chapter 6—Formation of Digital Mine Using the Internet of Things:** A digital mine is a simulated version of actual mining conditions on a computer screen. The condition of virtual reality is created through a basis on the Internet of Things (IoT),
with the aim of getting a vivid idea of prevailing underground situations and the monitoring of various mining parameters. These act as essential inputs for real-time decision making and the proper management of various mining activities including mining operations, looking into safety aspects, maintenance of congenial mine environments, rescue operation of trapped miners, restoration of mining conditions after an accident, the training of miners, etc. The IoT provides an infrastructure for sensing, collecting, processing and application of acquired information with the help of sensors, actuators, radio frequency identification (RFID) devices, CCTV, gateway, 3D display units, etc. Thus, digital mines open up a new scope for enhancing production, ensuring the safety of mines and miners, and providing safe working environments in mines.

Chapter 7—Application of Cloud Computing Technology in Mining Industry: Cloud computing systems, which are the latest versions of computing models available, have practically revolutionized the information technology. They distinguish themselves from other computing paradigms due to their unique characteristics such as the ability to handle massive data, the power of virtualization, scalability, elasticity, agility, resource pooling capability, and dependable security. Moreover, they are very cost-effective and usable for individual as well as industries. The mining industry, which is facing several challenges of varied complexities, can reap the benefits of this technology in different areas such as mine automation, knowledge sharing, process improvement, safety management, equipment condition monitoring, environmental impact assessment and management, environmental modeling, the tracking of miners and moveable mining machinery, asset management, and efficiency improvement in all facets of mining activities and remote operations. Cloud computing technology within a short period has already shown the potential for becoming a major driver of growth for several industries. It can help with enhancing production as well as increasing safety and thereby bringing economic benefits to the mining industry. This chapter narrates in detail about cloud computing technology including its deployment models, characteristics, implementation status and application in mines.

The book will be immensely useful for the scientists, professionals, geologists, geotechnical engineers, mining engineers, electronics and communication engineers, researchers, students, etc., who are closely associated with these subjects in connection with their work, research, and studies. The book will also be useful for practicing engineers as it covers comprehensive information on advanced technologies as well as the study of different types of sensors and their application for the monitoring of various mining activities, which are important for the cost-effective deployment of systems in the field used to minimize mining hazards, and enhance safety and productivity. Further,
the book contains complete details of the circuit diagrams for different systems developed by the authors so that the researchers and manufacturers working in the field may make use of these technologies for several applications.

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