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Application of Sensor in Mining Machinery to Recognise Rock Surfaces

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Abstract— the success of automation applications in the mining industry traditionally has not been well. In many of these cases the benefits of automation have been advertised as the definitive solution to a wide variety of problems faced by the mining industry, such as increased safety and improved productivity. These applications have in many cases been introduced prematurely without adequate consideration of the rigors of the mining environment.

As a result, effective technology has often been labeled as a failure before it has had a chance to demonstrate its true capability. Therefore, we believe that a major requirement is essential to develop automation technologies for mining systems or sub-systems, which needs minimal operator input requirement. This can be achieved in several ways. First, by narrowing the domain in which the automated mining system must operate such that less complex automation technology can be applied robustly. Alternately, more sophisticated control technologies are required that can react to the wider range of operating mining scenarios resulting from an uncertain, dynamic and very unstructured geological highly variable and unpredictable environment.

Automation of shearer machines, with the help of an opto-tactile sensor, should make the machine capable to detect the coal-rock interface in the roof and the floor. In this article an attempt has been made to apply, in association with an existing shearer machine, a newly developed opt-tactile sensor to detect different types of material layers where a shearer machine can operate at the longwall face of underground coal mines. The proposed tactile sensor should be capable to detect different types of materials (coal, limestone, sandstone, and shell) recognizing their surface textures.

Keywords—shearer machines, coalmining, rock/coal interface, automation, opto-tactile sensor

I. INTRODUCTION AND PROBLEM ORIENTATION

Shearer machines used in Australian underground longwall coal mining operations, consists of, as major units (Fig. 1), a driven rotating cutting head (cutting drum), range arm, hallway section (armoured face chain conveyor – AFC), control section, main body, squirrel cage induction motor, and speed reducer. The 5m long high torque rotating cutting head removes coal seams up to five meters thick from the coal-wall. The environment is noisy, dusty and potentially explosive. Making longwall coal mining safer and more productive has been the subject of a long-running CSIRO project funded by the Australian Coal Association Research Program, which has also come up with new technology designed to locate and guide coal-cutting equipment in longwall mines.

The downtime statistics of Australian longwall mining operations showed that 10 categories of machine-related failures accounted for 50 percent downtime [1]. Amongst the major ones are face alignment, horizon control, information system and open communication between subsystems. A fully automated shearer machine must include and address these issues. Currently, shearer automation refers mainly to horizon control, i.e. how to automatically control the shearer's cutting horizon so that it always stays in-seam and cuts a uniform thickness. In order to achieve this, the shearer must be able to recognize the coal-rock interface in the roof and floor of coal mines. Furthermore, once it determines the horizon of coal-rock interface, it must immediately adjust its cutting drum position. In addition to an onboard microprocessor that stores and analyses data and issues commands, an automated shearer system needs a coal-rock interface detection system and inclinometers for measuring and adjusting the drum height and body pitch.

The gamma ray coal thickness measurement system has been used to detect the coal-rock interface [2]. Gamma radiation is high in shale, lower in sandstone, almost absent in limestone and virtually undetectable in coal [3]. Natural gamma ray background (NGB) sensors are used in longwall coal mining operation for the detection of coal-rock interface. Many coal-rock interface detectors have been developed and tested, but all of them are still in the experimental stage. These are based on pick force, rock vibration and video camera [4] principles. A pick force measurement system determines the variation of cutting forces on instrument bits by identifying the special characteristics of the cutting force required to cut the immediate roof. This system is based on the principle that the cutting force required to cut the immediate roof in a coal seam differs from that for the coal. By processing the variation in pick force with an onboard computer, the coal-rock interface can be identified. To distinguish coal-rock interface a vibration assessment system utilizes the principle of differences between the vibration characteristics of the machine when cutting rock and that when cutting the coal. This system involves mounting one or more vibration sensors as close to the cutting drum as possible [5].

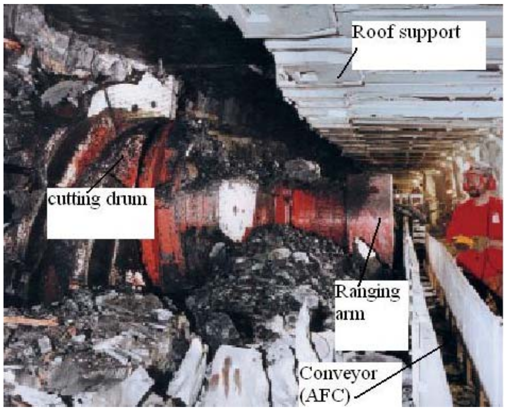

Figure 1. ***Shearer machine model EL 1000/3000 (courtesy DBT).***

A shearer requires two operators, one for the head cutting drum and the other for the tail drum. Their objective is to control the drum's cutting horizon to stay in seam at all times. Their normal practice is to rely on one or more consistent partings or bands in the coal seam to guide them. This works well in most of the cases for the leading drum that cuts the top coal. But, it would not work for the trailing drum because of the floor is normally covered with bottom coal and the Armoured Face Chain Conveyor (AFC). So the first step of shearer automation is to control the cutting horizon of the drums. A gamma ray sensor is designed for this task.

After the shearer's cutting pass, shields at a predetermined distance behind the shearer will have to be advanced followed by pan push. In order to accomplish this task, the shearer's position must be known at all times, and this information has to be relayed to the shield to be advanced for action. This task is accomplished by the infrared sensor or the proximity sensor.

Overall an automated shearer system requires the following sensors:

- An infrared sensor and/or odometer to determine the location of the shearer at all times.
- A gamma ray detector or opto-tactile sensor for determining the coal-rock interface.
- Two inclinometers for controlling the height of the ranging arms or the cutting heights of the drums.
- Inclinometers for determining and controlling the pitch (in the mining direction) and roll (in the face line direction) of the shearer.
- Shields with electro-hydraulic control system.

A schematic of an automatic control longwall shearer system is displayed in Fig. 2. The system [6] has headgear computer in communication with three separate computers such as a surface station with screen display for management control, a shield central station for interface with shields, and an onboard shearer computer that processes sensor data and control shearer operations. Modern longwall mining employ self advanced power support (or shield support) at the face area. It supports not only holds up the roof, pushes the armoured face chain conveyor (AFC), and advances itself, but it also provides a safe environment for all associated mining activities.

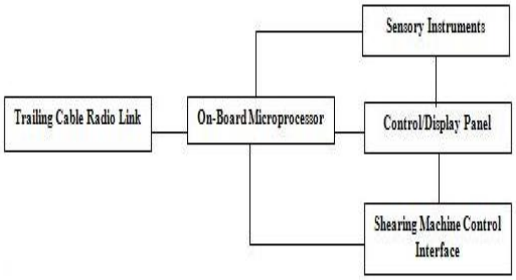

Figure 2. ***Control Scheme of a Robotic shearer machine for coal mining***

The robotic shearer can be operated in several modes: speed control, coal rock interface tracking, replicate roof cut, fixed-height roof cut, and gate-end cut-out. For instance, in the replicate roof-cut mode, the amount of roof coal thickness to be left is determined first. In the initial run, say from the head-to-tail trip, the ranging arm position sensor (or inclinometer) will adjust the cutting horizon based on the reading of the gamma ray sensor at a fixed interval. This information is stored in the computer and guides the ranging arm position sensor in the next trip from tail-to-head and on subsequent trips. The replicate roof cut can be replaced on command or when and if the system determines the change is needed. The robotic control system has demonstrated [1] that it can conduct mining in adverse conditions by successfully mining through a significantly disturbed zone of the coal seam (Fig. 3).

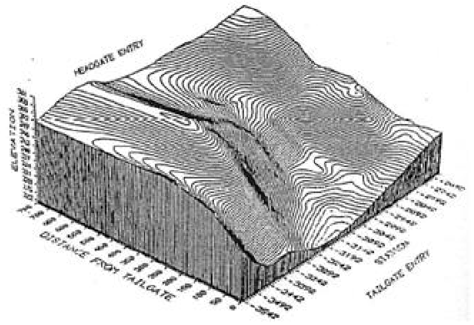

Figure 3. ***Automated shear system successfully negotiated in the disturbed zone of a coal seam.***

The longwall mining system [1, 11] consists of the following subsystems: the shearer, shields, AFC, stage loader, belt conveyor. Each subsystem consists of one or more components. For a longwall system to operate continuously, all subsystems and their components must be integrated or automated in order to reach the full potential of a continuous mining system. Today, most subsystems are either partially or fully automated. In order to be automated, subsystems and subsystem components must be able to communicate freely amongst each other. Communication consists mainly of data recognition and/or confirmation for action to be taken.

In order to implement the subsystem components and subsystem integration, communication links between subsystem components and subsystems must be established. Communication involves access to and/or providing monitored data to dedicated computers in subsystem components or subsystems. The communication system runs on an Ethernet network, very much like the commonly used electronic mail network. Each subsystem has its own computers and can operate on its own even if the network is down. If the network is down, communication between subsystems is interrupted. On the surface, the host system includes the server, network controller, and processor as well as monitor. There are also PCs, work stations, and laptops connected to the network. In the longwall section, the shearer is hardwired and its data is transmitted through modern-modem to power centre. The shearer also can communicate with the shields through a wireless system such as infrared transmitters/receivers.

II. SURFACE TEXTURE OF OBJECTS

Object surface texture, in general, can be characterized by surface roughness and surface irregularities or waviness [7] as depicted in Figure 5. Although it looks but in no cases any surfaces are perfectly smooth and plane, every surface always has some sort of roughness texture. For machined or cast, or a product produced by any other processes a particular surface is created as a result of the particular processes and tool actions and / or procedures and their scientific phenomenon leaves its consequences on a surface to create surface waviness and roughness. Other products in nature obtain their surface by natural phenomenon. Such as stones and coals obtain their surface integrity by nature as these were produced day by day in nature one under huge pressure and the other as a result of volcanic eruption. Presumably, the surface textures of coal and that of stones are also influenced by their crystalloid structure and bonding, as well as crystal phase.

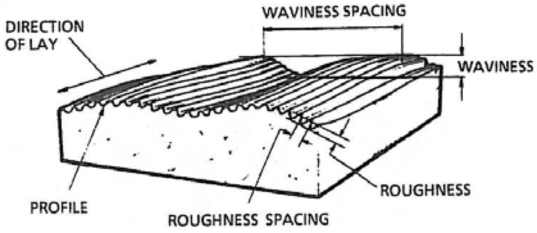

Figure 4. ***Surface characteristics***

Surface roughness or waviness is characterized by the geometry of their peaks and valleys (Figs. 4, and 5). Using a tactile sensor or a stylus, surface texture variation can be assessed by geometric parameters such as rise angle (α), height (h) of one peak from the corresponding valley, and distance (l) from a peak to the next one. The motion of a tactile or a touch of a tactile sensor can specify those geometric parameters of a surface.

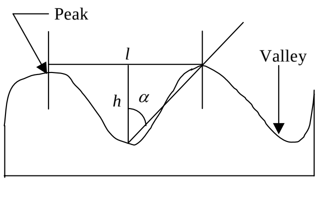

Figure 5. ***Geometry of surface roughness***

III. APPLICATION OF TACTILE SENSORS IN SHEARER MACHINES

Objects can be sensed by vision, hearing, smelling or touching; by touch can be contact and non-contact sensing [7]. Knowing the nature of surface texture of certain object it is possible, for a robot or intelligent systems, to create an approximated idea for recognition of the object. Each and every object such as coals, concrete, tiles, carpet, floor vinyl, road surface or wall, a piece of stone or timbre, a bolt or a pin, machined product or cast product, in a word, every object in nature has its own surface structure, phase, and texture integrity. Therefore sensing of surface texture and structure can allow partial recognition of object, in some cases full recognition may be possible. In this particular work tactile type sensor is used to sense surface texture and recognize it. For these purposes the more successful artificial skin type tactile sensor was designed and fabricated by Patterson and Nevill [8] called as induced vibration touch sensor (IVTS) for object surface assessment.

Currently the authors are exploring capabilities of tactile sensors to use in design of underground coalmining shearer machines to sense and differentiate coal and rock surfaces. An opto-tactile sensor has reasonably proven by a series of experiments [7, 9] its capabilities to distinguish and recognize surface textures of different non-fluidic objects by touch. Evidently coal surface and stone surfaces are different in nature of surface texture integrity. The experimental procedure for recognition of coal and stone surfaces and distinguishing them according to surface texture integrity is underway.

Literature survey shows that, a finger-shaped tactile sensor based on optical technology have been offered by W. Lo, Y. Shen, and Y. Liu (2001) and it has been applied [10] to capture tactile image of the touched area of an object. As shown in Fig. 6, the given finger-shaped optical based tactile sensor is consisted of a transparent and flexible rubber optic wave guide covered by an elastic membrane, an organic glass support, a group of lenses, an optical fiber image cable, micro-light sources, and a CCD device. According to authors, the light sources are accommodated in pipes to avoid scattering of light. The light is injected into the optic wave guide. If no object is in touch with the sensor, the light is reflected internally inside the rubber optic guide and no light rays are passing on to the lenses.

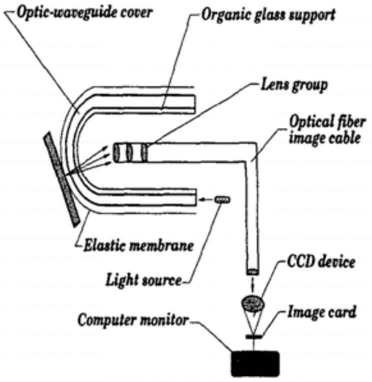

Figure 6. ***Optical based finger-shaped tactile sensor***

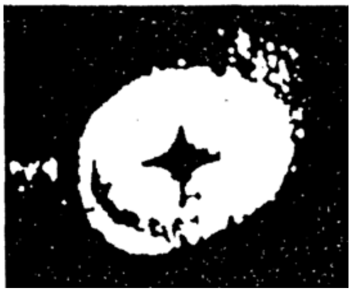

Figure 7. ***Image of a cross-head screwdriver head touched by the sensor***

We are attempting to use opt-tactile sensor/s for further automation of shearer machines in underground coalmines. Tactile sensors, involving arrays of force sensing elements are recognized as a principal need for next generation robots [7], and so as for intelligent systems. Potential robotic applications require some form of sensing.

IV. AN OPTO-TACTILE SENSOR

The opto-tactile sensor system can be used for assessing rock and coal surface textures for recognizing a particular surface texture. The sensor works on the principle of fiber optics technology [7]. The design and working principles of the set-up is depicted in Fig. 8. It is consisted of a small piece of full-silvered mirror, a tactile-pin, a light emitting diode (LED), a phototransistor, two pieces of optical fiber cable, flexible rubber body with bumps / fingerprints /nibs.

As described in [7], the full-silvered mirror is perpendicularly mounted on the inner end of the tactile pin rigidly. The other end of the tactile is introduced into a bump of the elastic rubber body, which resembles a human hand, and the bumps as fingerprints. As if it is hinged to the middle part of the bump of the rubber body, it allows rotating around the imaginary hinge joint during its deflection. A light-emitting diode (LED), as a primary light source, is used to emit light rays through one of the fiber optic cables.

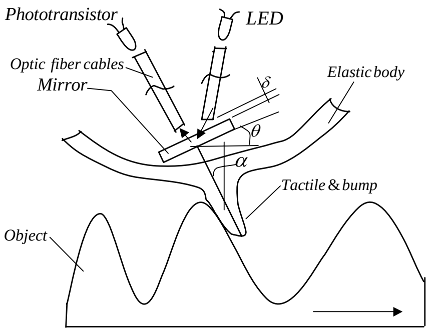

Figure 8. ***Opto-tactile sensor for object surface recognition.***

The propagated light ray passes through the optical fiber carrier, as explained in [7], focusing on the full-silvered mirror. Some portion of the reflected part of the propagated ray is immediately returning back through the second optical fiber carrier and it is received by the phototransistor. The second ends of the carrier and receiver fiber optic cables are located equally at a distance of $\delta = 0.50mm$. These components are accommodated in a foamy mass to keep their proper relative locations. The signal from the transistor is processed by an Infineon C167 microprocessor assembled in a PHYTEC KitCON-167 evaluation board using MATLAB® software. A photograph (Fig. 9) of the opto-tactile sensor system more visually displays its major components in assembly.

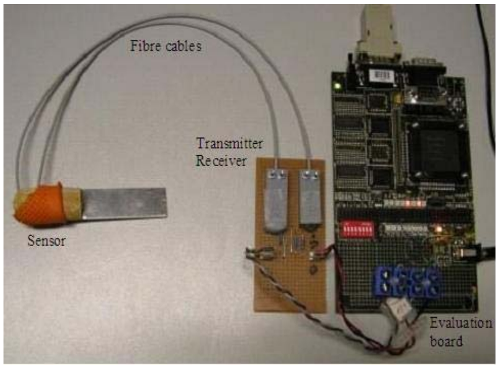

Figure 9. ***Assembly of opto-tactile sensor***

Intensity of light propagation at the second end of the receiver cable is proportional [7] to the geometrical parameters of the surface texture such as height, pitch-length of the peaks, and angle of inclination of individual peaks. The relationship can be expressed as follows:

$$I = f(l, h, \alpha) \tag{1}$$

Where,

I = Intensity of reflected light received by the phototransistor from the second end of the receiver cable;

l = Pitch distance between two consecutive peaks of surface texture;

h = Height of a peak, from the valley, the stylus is in contact at some stage;

α = Angle of rise of a peak from the valley (Fig. 5).

Considering an object surface is a plane one, there is no deflection of the tactile bump. Therefore the intensity of the propagated light ray achieves the highest value, and let it be denoted by $I_{\max}$. That means if $\gamma = \theta = 0$, then $l = 0$, $h = 0$, and $\alpha = 0$.

Where, γ = angle of inclination of the tactile bump (Fig. 6). The tactile is rigidly and perpendicularly attached to the mirror. Therefore, it is evident that, $\theta = \gamma$.

Now considering a textured surface as depicted in Fig. 6, where there is at least some deflection of the tactile bump, which changes its angle γ depending on the surface texture geometry. We can assume, in any case the relation between γ and θ is expressed as follows:

$$\gamma = \theta$$

Analyzing the geometry of a single peak and corresponding valley as shown in Fig. 9, we can write,

$$\tan\alpha = \frac{l/2}{h} = \frac{l}{2h} \tag{2}$$

Therefore,

$$I_{\max} \propto \tan\alpha = \frac{l}{2h} \tag{3}$$

Therefore, for general cases we can express

$$I \propto \tan\alpha \quad \text{and} \quad I \propto \frac{l}{2h} \tag{4}$$

Taking into consideration a coefficient eqn. (6) can be rewritten as follows:

$$I = C\frac{l}{2h} \qquad (5)$$

Or

$$C = \frac{2hI}{l} \qquad (6)$$

Where, C is the coefficient of intensity for the system.

Using any one of these two equations (5) and (6) it is possible to assess surface texture of any object with the help of the developed mechanism.

V. EXPERIMENT

It is proposed to carry out a reasonable amount of real life experimental works so that the developed opto-tactile sensor can be used for automation of shearer machines, since the sensor has been experimented [9] for recognizing surfaces of objects like cast iron surface, tabletop, and floor carpet. The results of the experiments have been demonstrated and can be revisited (Fig. 10).

The laboratory experiments which have been successful for surfaces of cast iron, floor carpet and table top, is an advantageous example that similar result for researching coal and stone surfaces can be achieved. A series of laboratory real life experiments is underway and divided into three stages: (a) adequate number of stone and coal samples collection from the real mining areas, (b) following the procedure as described in [7, 9], and (c) using modern soft computing technology processing method development for object (coals or rocks) recognition.

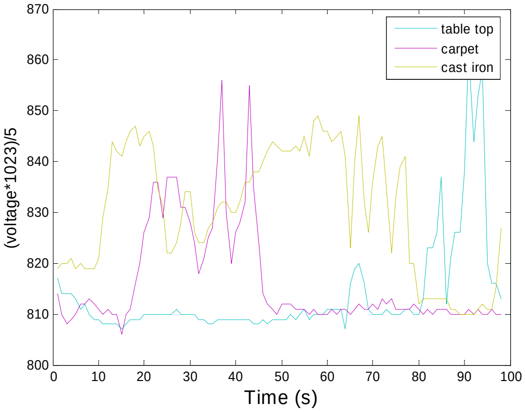

Figure 10. ***Surface texture evaluation by opto-tactile sensor***

The obtained results processed by the tactile sensor unit with the help of soft computing technique can be used in industrial shearer machines interfacing with the main control system of the shearer machine.

CONCLUSION

Application of automated shearers has produced the following benefits:

Increased coal recovery and quality – since cutting always stays in-seam, run-of-mine coal is much cleaner. In addition, the boundary coal in many coal seams contains higher sulphur content; leaving top coal will enhance product quality.

Enhanced roof control – the immediate roof in many coal seams is weak and some top coal must remain to protect it. Automatic horizon control can make this happen easily and consistently. The roof and floor are much smoother. Supports can have better or full contact with the roof and floor, and eliminates severe rolls in both the face-line and mining directions. The mining height is also more uniform from cut to cut.

Tactile sensors can be effectively used in mining machinery automation systems which may bring potential benefit for the mining industries. In particular the opto-tactile sensor described in this article has potential to use it for distinguishing coal-rock interface recognizing coal and stone surface textures and integrity.

REFERENCES

[1] ***Hookham, M., Study identifies delays, Australia longwalls, a technical report, Australia. 2003. 43pages (unpublished).***

[2] ***Mowrey, G. L., Horizon control holds key to automation, Coal, Australia Part I, December 1991, pp. 44-48, Part II, January 1992, pp. 47-51.***

[3] ***Nelson, M. G., Simulation of boundary coal thickness sensor, PhD Dissertation, Department of Mining Engineering, West Virginia University, 1989, pp. 153 pages.***

[4] ***Kelly, M., Outcome of the landmark longwall automation project with reference to ground control. Proceedings of 24th International Conference on Ground Control in Miningh, West Virginia, August 2005, pp. 66-73.***

[5] ***Kurdo, H., Nishimura, K., and Esaki, M., Integrated automation of longwall mining system, Coal Power'87, The AusIMM Annual Conference, Newcastle, Australia, 1987. Pp. 143-152.***

[6] ***Bessinger, S. L., A review of CONSOL longwall innovation, Proceedings of longwall USA Conference and Exhibits, Pittsburgh, PA, June 1996, 16 pages.***

[7] ***M. A. Mazid, R. Andrew Russell, A Robotic Opto-tactile Sensor for Assessing Object Surface Texture, Proceedings, 2006 IEEE International Conference on Robotics, Automation and Mechatronics (RAM 2006). Bangkok. 2006. Pp. 387-391.***

[8] ***Robert W. Patterson, Gale E. Nevill, Jr., The induced vibration touch sensor – a new dynamic touch sensing concept. Robotica, vol. 4. 1985. pp. 27-31.***

[9] ***M. A. Mazid, M. Fakhrul Islam – Grasping Force Estimation Recognizing Object Slippage by Tactile Data***

Using Neural Network. 2008 IEEE International Conference on Robotics, Automation and Mechatronics (RAM 2008). Chengdu, China. June 2008, Pp 935-940.

[10] ***Wang-tai Lo, Yantao Shen, and Yun-hui Liu, An integrated tactile feedback system for multifingered robot hand, Proceedings of the 2001 IEEE/RSJ International Conference on Intelligent Robots and systems. Maui, Hawaii, USA, 2001. pp. 680- 685.***

[11] ***R. Andrew Russell, Robot Tactile Sensing. Prentice Hall. 1990.***

[12] ***Peng, S. S., Longwall Mining. ISBN: 0-9789383-0-5. Publisher: West Virginia University, USA, 2006.***