Thermal imaging technology has an important role to play in accident prevention for mine vehicles.

Thermal imagery to prevent pedestrian-vehicle collisions in mines

by John Dickens, CSIR Centre for Mining Innovation

Mine vehicle accidents are second only to rock-falls in terms of the number of fatalities they cause. The number of deaths in South Africa’s mines annually has decreased from approximately 290 in 2001 to 123 last year, indicating that the mining industry has made good progress towards improving safety, but there is still a long way to go.

Approximately 20% of the mining industry’s fatalities can be attributed to vehicle accidents. With new legislation imminent, collision avoidance systems for mine vehicles are poised to become an essential part of safety systems in mines.

Thermal imaging involves the detection of infrared (IR) radiation emitted by various objects in the area being imaged. All objects with a temperature above absolute zero emit electromagnetic radiation. This radiation is spread over a wide band of frequencies but the peak frequency depends on the temperature of the object. The amount of radiation depends on the object’s temperature and its emissivity.

Thermal IR cameras use the amount of radiation in the long-wave infrared (LWIR) band to determine objects’ temperature using data of their emissivity.

The IR band of the electromagnetic spectrum is wide, with a number of sub-bands, each with different characteristics and uses (see Fig. 1). Near IR is most commonly used for remote controls and commercial day/night surveillance systems as it is simple to produce and to detect but invisible and unintrusive.

Short-wave IR is used primarily for military night vision systems. Mid-wave IR is used for imaging hot objects and for monitoring furnaces or for astronomy. Long-wave IR corresponds to the wavelength of IR radiation emitted by objects that are colder than a few hundred degrees Celsius and is therefore used mostly for thermal imaging.

Fig. 1: An illustration of the IR sub-bands and their uses.
Long-wave IR is appropriate for detecting people in the vicinity of underground mine vehicles. It is completely passive and there is no need for external illumination. This means that persons can be detected in the thermal image even before they enter an area illuminated by the vehicle’s head-lights. Thermal IR light also penetrates dust better than visible light because of its long wavelength.

The most popular existing proximity detection systems for mine vehicles are radio frequency identification (RFID) tag based systems. RFID-based systems operate by fitting a tag to every worker and a tag reader, or readers, to the vehicle. The exact method used depends on the system but essentially the reader continuously sends out an electromagnetic “ping”. When a tag is within range it will respond with its unique identification number. The system then knows that there is a person within a certain distance from the vehicle. If the vehicle is fitted with multiple receivers it can also determine the approximate direction as well, i.e. the person is some distance in front of the vehicle. RFID-based systems are effective in many circumstances but are not the solution in every circumstance. To reduce development costs it is common for hard-rock mines to have rail-bound equipment and personnel travelling next to one another within a single tunnel.

Every time a locomotive passes a pedestrian in one of these tunnels they will be in close proximity even if the pedestrian is not in danger. For this reason we would like to know exactly where the personnel are and whether they are in danger or not. This is the application that thermal image based pedestrian detection was aimed at, detecting whether someone near an underground locomotive is in danger or not.

The pedestrian detection system identifies people in the thermal image, and then, using a distance sensor, determines exactly where the person is in relation to the vehicle. This process is repeated rapidly for every thermal video image. The system then detects which person in one frame corresponds to the same person in the consecutive frame. Knowing how the person has moved from one frame to another allows us to predict the trajectory of the person and thereby determine whether they are on a collision course with the vehicle. Once we know whether the person is on a collision course with the vehicle, we can estimate when the collision will occur. This is useful, for example to determine whether some action must be taken immediately or whether the person has time to move out of the way of the vehicle.

The pedestrian detection process consists of a number of steps, as illustrated in Fig. 2. The first step is to identify warm areas in the thermal image. These regions of interest are areas that have a temperature sufficiently different from the surroundings to indicate that they potentially belong to a person. The next step is to determine which of the regions of interest actually represent a person. This is done by extracting pertinent features from the region of interest and using a classification algorithm to decide whether that region is in fact an image of a person.

Fig. 2: An illustration of the pedestrian detection system steps.