Thermal imagery predicts pedestrian-vehicle collisions in mines

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Thermal imaging technology has a number of characteristics that make the technology a good choice to prevent vehicle-related accidents in mines. Vehicle-related mine accidents are a major cause to mine fatalities which means that effective collision avoidance systems are an essential part of any mine’s safety systems.

Mine-vehicle accidents are second only to rock-falls in terms of the number of fatalities that they cause [1]. The number of fatalities in South Africa’s mines has decreased from approximately 290 in 2001 to 123 last year, indicating that the mining industry has made good progress improving safety but there is still a long way to go. The approximately 20% of the industry’s fatalities that can be attributed to vehicles can be prevented through the correct introduction of safety systems. With the imminent introduction of new legislation [2], collision avoidance systems for mine vehicles are poised to become an essential part of mines’ safety systems.

Thermal imaging involves the detection of infrared (IR) radiation emitted by various objects in the scene being imaged. All objects with a temperature above absolute zero emit a certain amount of electromagnetic radiation. The emitted 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 temperature of the object and its emissivity. The amount of radiation in the long-wave infrared (LWIR) wavelength band is what a thermal IR camera uses to determine the temperature of objects (using knowledge of their emissivity).

The IR band of the electromagnetic spectrum is a wide band with a number of sub-bands each with different characteristics and uses, as shown in Fig. 1. Near IR is most commonly used for remote controls and commercial day-night surveillance systems. This is because it is easy to produce and detect but is not visible and is therefore not intrusive. Short-wave IR is used primarily for military night vision systems. Mid-wave IR is used for the imaging of hot objects and is used for the monitoring of furnaces or for astronomy. Long-wave IR corresponds to the wave-length of IR radiation emitted by objects that are colder than a couple hundred degrees centigrade and is therefore used primarily for thermal imaging.

Long-wave IR has a number of advantages that make it appropriate for detecting people in the vicinity of mine vehicles, in particular underground mine vehicles. The first advantage is that long-wave IR imaging is completely passive; there is no need for external illumination. This means that someone can be detected in the thermal image before they are in an area illuminated by a vehicle’s head lights. Additionally the long wavelength of thermal infrared light means that it penetrates dust better than visible light.

There are a number of existing proximity detection systems for mine vehicles [3-6]. The most popular of which 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 is 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 such a 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.

The system is currently being commercialised by Ubora Innovation in conjunction with the CSIR Centre for Mining Innovation and additional extensions of the system are being considered, such as adapting the system for trackless vehicles and the recording of pedestrian detection information. Trackless vehicles may require multiple sensors distributed around the vehicle and additional information from the vehicle, such as the steering angle to allow the system to take into account the fact that the trajectory of a trackless machine is less predictable than that of a locomotive. Recording the pedestrian detection information would provide a number of benefits, especially for accident investigations.

Thermal imaging provides an effective way of detecting and tracking personnel near mine vehicles. Knowing exactly where the people are near a vehicle and tracking them allows the system to predict whether a collision is likely as opposed to simply reacting to the presence of a person near the vehicle. In addition to pedestrian detection for mine vehicles, there are also a number of alternative uses for automatic human detection underground. One of the potential uses is for underground surveillance without the need for someone who is permanently watching a surveillance feed. It could be used to detect whether people, for example illegal miners, are entering a restricted area of a mine.

References


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