HAUL TRUCK ALIGNMENT MONITORING AND OPERATOR WARNING SYSTEM

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ABSTRACT

This paper presents a haul truck alignment monitoring system that provides early warning signals to the operator when the truck is about to lose control. It is considered that a truck is in this condition when it crosses the centre of the road or veers to the side of the road at speed in an uncontrolled manner. The system provides different levels of warnings to the driver and other haul trucks in visual contact. The system is based on a laser range and bearing sensor that measures the relative distance to standard PVC poles located at the side of the road. Using this approach a high level of accuracy and reliability can be achieved with low cost since the installation and maintenance of the infrastructure does not require special expertise or expensive machinery. The system also logs raw sensor data and warning events generated by the truck. This information is downloaded using IEEE802.11 based wireless interfaces to standard PCs or PDAs for post-processing. This is essential to detect operator’s microsleep events early enough to implement pre-emptive actions to avoid or reduce fatigue related accidents. The wireless capabilities are also used to detect the presence of other trucks or utility vehicles incorporated into the system.

INTRODUCTION

Each year, hundreds of mining haulage accidents occur, resulting in a significant number of deaths and injuries as well as costs through replacement, repair and downtime. Many of these accidents are due to microsleep events that are a manifestation of operator fatigue. This issue has been researched extensively and it has been demonstrated that humans will have a significant number of microsleep occurrences per shift when they are required to work at night [Sirois]. During these events the driver loses control of the truck for a short period of time. This is becoming a more important issue where larger truck are introduced without a corresponding enlargement of haul road widths. Most mines manager are now more aware of these problems and are starting to take a more active role in supporting the development of new operator fatigue systems.

![Figure 1 Incident due to truck veering to the side of the road](image)

A frequent cause of accidents in hauling is the truck driver falling asleep and losing control of the truck. The truck then crosses the centre of the road or veers to the side. Figure 1 shows the results of one of these accidents, where the truck veered to the side of the road.

Some existing approaches are based on keeping the operator alert by requiring some sort of interaction at random times. The problem with these approaches is that the operator can become used to these warnings and start generating this interaction as a reflex action without being fully aware of what they are doing. While this problem has been addressed with systems requiring more sophisticated interactions these can be too distracting for the operator.

There are also a large number of indirect methods that attempt to detect operator fatigue related behaviours such as: encoders in driving wheels to detect particular oscillation in the trajectory of the truck; mercury switches to detect changes in the pose of the driver; and a camera system to detect the movements in the operator eyes, etc. In general none of these systems have demonstrated the reliability required to detect microsleep under all possible conditions.

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Other systems available generate alarms when the haul truck is close to other mobile vehicles / trucks. Although this approach addresses the proximity problem it fails to provide an early warning of the “truck out of control” conditions. For example two haul trucks moving at 60 km/h (17 m/sec) will be 100 metre closer in 3 seconds, not enough time to allow the operator to correct the problem in time. In addition these systems do not provide information regarding a potential collision and in most cases generate irrelevant warnings / or no warning at all when travelling at speed.

The system presented in this paper addresses the problem by continuously monitoring the position of the truck in the road in a very reliable manner. The system is based on measuring relative distances from the truck to a virtual wall formed with PVC poles placed at the side of the road. The system has been successfully trialled in various mine sites.

**MAIN TECHNICAL ISSUES**

An effective haul truck alignment monitoring and operator warning system must warn the operator when the haul truck deviates from a valid operating corridor, while also alerting other trucks of the potential hazard. One of the fundamental issues in this application is the accurate determination of the position of the truck in the haul road. There are several different approaches to solve this problem. One is to obtain the absolute position of the truck with a navigation system and compare this pose with a given haul road map. Global positioning systems (GPS) are available with the accuracy required for this application but there are fundamental problems with availability of this accuracy when working 24 hours/day, 7 days/week. The GPS sensor can be augmented with inertial technology [Sukarieh] but the cost of a satisfactory system for this application is high. There are other approaches to obtain high accurate absolute position [Nébot] [Guivant] but these methods require significant infrastructure and maintenance to achieve the level of integrity required in this type of environment.

Another way to address this problem is to obtain the position of the truck relative to the side of the road. In this case an accurate relative observation to a feature known to be at a certain distance from the centre of the road can be obtained. Therefore the position of the truck in the road can be inferred assuming a constant width haul road.

There are various sensors capable of providing information about the environment to solve this problem, such as vision, radar and laser. Vision is not appropriate for this application due to the lack of robustness with respect to different lighting conditions. Prototypes of millimetre wave radars are available but the cost is too high for this type of application. Lasers are a viable option and offer a compromise between robustness and cost but one of the major drawbacks of laser based sensors is environmental conditions. These sensors are affected by dust and fog and require periodic cleaning to maintain the laser windows to avoid excessive attenuation. For these reasons it is essential to select not only the location of the sensor but also the regions where it will be searching for the features. The later will determine the type of features that will be reliably detected under all possible environmental conditions.

Figure 2 shows typical haul roads in a mine type environment. It is clear that there is no relevant natural features that can be used to infer the position of a truck in the road with the required accuracy. This means that there is a need for some sort of artificial infrastructure.
Figure 3 shows two different examples of artificial infrastructure: bund walls at the side of the road and PVC poles.

Figure 3: The haul road is bounded by bund walls. PVC poles are also displayed on top of the bund wall.

A range and bearing laser can be used to detect the boundary of the road determined by the bund walls. This process can be improved by assuming the geometry of the bund wall is known. Although this approach can be made to work in some cases, it is clear that it has some drawbacks. The fundamental problem is that the accuracy is difficult to predict and at the same time requires significant resource allocations for the proper maintenance of the bund walls. Another potential problem is that the sensing device needs to look for infrastructure where the environmental conditions are usually worst, especially for this type of sensors. On the other hand the infrastructure based on PVC poles can be installed and maintained with low cost and utilizing basic resources. It is also easy to detect an improper installation such as the two first poles in Figure 4a. It can also tolerate more difficult environment conditions such as the one in Figure 4b since the sensor is looking for infrastructure far above ground level.

Figure 4a. Simple visual inspection is needed to detect that first two poles are not placed correctly. 4b: Under some environmental condition the laser may not be able to detect infrastructure close the ground.

SYSTEM IMPLEMENTATION

The system uses a scanning laser to detect existing guideposts by measuring the time of flight of the laser light pulses. The pulsed laser beam is deflected by an internal rotating mirror so that a fan-shaped scan is made of the surrounding area.

The system calculates the distance of the haul truck from a virtual wall formed by the guideposts as shown in Figure 5. The figure shows a valid and normal corridor that is set with a configuration file to provide early warnings. When the truck veers too far off course, the system issues a series of staged warning signals to alert
the operator including both visual and audible alarms. As shown in Figure 6, the system can accept special infrastructure to indicate the presence of intersections or the entrance to the mine. In this case a given rule is applied to generate a particular level of warning. For example, when approaching the intersection this type of infrastructure could provide a warning to the operator.

Furthermore, if this alarm is acknowledged the system can then allow the truck to cross the centre of the road to take the intersection without generating a full alarm.

Figure 5: The system monitor the infrastructure to determine the position of the truck in the road.

Figure 6: Three poles at a fixed distance indicates a type of special infrastructure.

The system is integrated with other sensors such as GPS to provide details of the speed and location of the vehicle. The GPS is not an essential component of the system and is used mainly to enhance the reporting capabilities. The full system consists of a main processor box, laser sensor, warning lights, audible alarms and operator interface box as shown if Figure 7. It is completely independent to the rest of the truck requiring 24 V power from the truck to operate.
The warning lights are placed on the roof of the truck and flash when the alarm is activated, to warn on-coming drivers of a truck veering off course. This is an improved safety benefit for all trucks in the fleet and gives the other drivers an opportunity to take evasive action.

The system logs 12 hours of real-time information of the position of the truck in relation to the road as well as time stamped alarm events and raw sensor data for the last period of operation. This information can improve the overall safe and effective management of haulage in open cut mines. The data can be downloaded through a wireless link to the control room for post-processing.

**EXPERIMENTAL RESULTS**

The system was implemented and trialled in two different sites, Weipa, Comalco in Queensland and Willowdale, Alcoa in Western Australia (Figure 9). These two mines are completely different since Weipa mainly consists of very large flat roads and Willowdale has roads with small radius (ratio?) of curvature and significant slope.
The system’s components and installation in a haul truck is shown in Figure 10. This corresponds to the installation in a Komatsu truck in Alcoa in December 2003. Figure 11 presents the tracking process of the system. In this case the laser receives returns from all the objects next to the truck such as trees, cuts and PVC poles. The system is responsible for extracting the poles from this information. The figure shows the raw laser information as ‘*’ and the virtual wall formed with the PVC poles as a dotted line. With this information and the configuration file the system evaluates the normal and valid corridors and applies the rules appropriately.

It should be noted that although the standard rules should work appropriately for most mine operations, they can also be adapted to a particular mine. The system has elaborated algorithms to obtain high accuracy positioning of the truck in the road. At the same time autonomous GPS position and velocity is available. The trucks and vehicles integrated into the system will form a temporary ad hoc wireless network when in proximity to each other. This information and the capabilities available can be used to create a set of additional rules that not only improve safety but also productivity.

Figure 10 The system and its installation in the Haul Truck. The two warning lights and laser are shown in the front and side of the haul truck respectively.
CONCLUSIONS
This paper has presented a solution to the problem of generating an early warning to a truck operator, and other trucks in the area, that truck is out of control. The truck “out of control” condition is defined as the truck veering to the side of the road or crossing the centre of the haul road at speed. Although this system is under constant improvement it is already a commercial product manufactured by Acumine Pty. Ltd and distributed by Komatsu. Future work will address the efficient integration of proximity information and near-real time analysis to increase system safety.

REFERENCES