Paper 1115

Sensing technology applications in the mining industry – Short Review

J. Duarte[a], J. Castelo Branco[a], F. Rodrigues[b] & J. Santos Baptista[a]
[a] PROA/LAETA, Faculty of Engineering, University of Porto, Portugal
[b] RISCO, Civil Engineering Department, University of Aveiro, Portugal

Introduction

Industry 4.0 is reflected in a technological evolution in all economic sectors, leading to an improvement in traditional risk factors. It has introduced complex problems that can only be solved through advanced sensing solutions [1]. Exploitation sites are dynamic places that keep evolving overtime. Due to its natural challenges and in spite of all the technological development, this industry is still considered as one of the most hazardous especially in underground context [2]. Industry 4.0 technologies have made it possible to relate variables of entirely different origins, such as those related to the production process, and those related to environmental and occupational concerns, in real time. But in what extent are they integrated? This short review aimed to identify what type of sensors are implemented and how they are used to promote safety in the extractive industry.

Methodology

The conducted research followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) Guidelines [3, 4]. The keywords were divided into two main groups: one related to sensors (“sensor”, “cyber physical”, “internet of things” and “virtual reality”) and the other related to the interest field (“open pit”, “open cast”, “extractive industry”, “quarry”, and “underground mine”). Since the scope of the systematic review was related to equipment, the keywords “heavy earth moving machines” and “mining equipment” were also included as in the second group. The selected databases were Scopus, INSPEC, Science Direct, and Web of Science. The following exclusion criteria were used to filter the information: (1) date—only papers published between 2017 and 2021 were included; (2) type of document—only research articles were included; (3) type of source—only peer-reviewed journals were considered; and (4) language—only English written articles were included in the study. The applied inclusion criteria were related to setting: any article providing information in any environment other than real context (underground or surface mining) was immediately excluded. After this selection process and following the snowballing technique [5], all of the studies before 2017 were assessed and their scope was analysed for possible inclusion. The risk of bias across articles was assessed using The Cochrane Collaboration tool to assess bias [6] adapted to the systematic review scope (engineering field).

Results and discussion

Following the different stages proposed by the PRISMA Statement, it was possible to include 29 articles in this short review. The research flowdiagram can be seen in Figure 1. The majority of the included studies took place or tested their protocols in a mine setting (22 out of the 29 included articles). Though it cannot be discerned why, a hypothesis is put forth here: mining commodities require more complex processes (in terms of exploitation and processing). Therefore, more sophisticated answers are require to address the raised issues. Moreover, this cannot be set apart from the fact that 12 out of the 22 occurred in an underground setting, which usually brings to the table other concerns, especially related to safety. In open-pit, the focus is on slope stability and the prevention of accidents with heavy equipment. Safety is not the main focus of sensors’ use, but rather environmental (geologic mapping, land cover) and production (issues, with real-time monitoring of land use and mine development). Independent of research objectives, a sensors’ purpose is to collect information and monitor (something). The classified monitorisation fields were, again, safety, but also prediction, mapping, management, maintenance, and localisation. Almost every system setup was sustained by a wireless network. Despite the low application cost, this type of connectivity can have some implementation challenges, such as signal interference (and path loss), limited energy drive, and physical collision or barriers [7]. Zigbee networks can offer an alternative, overcoming some of these matters, as they operate with low power consumption, and the nodes can communicate between themselves, despite their low data rate [8]. On the other hand, Brillouin scattering shows great promise in the fields of geotechnical and civil engineering because of its extended range [9]. Current sensing technology does not end at these examples. Several systems are being developed every day. Optimal haulage system through measuring truck travel time [10]. miners position for rescue in case of an accident [11], road condition monitoring [12], rock sizing [13], hoist control [14], and, autonomous equipment [15] are some of the future promises that are now at one’s disposal.

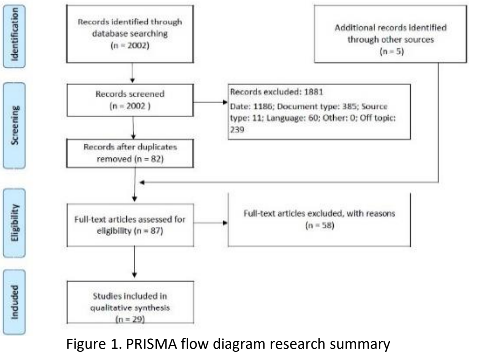

Figure 1. PRISMA flow diagram research summary

Conclusions

Industry 4.0 can promote safety by designing more efficient and safer production processes. The tested solutions displayed different levels of implementation, varying from prototypes, trial or implemented systems, found across various sub-processes such as blasting, environment, exploitation, exploration, production, recovery, transport and ventilation. By using sensors to monitor activities, collision prevention and real-time stability monitoring of soils and tunnels are some examples of the real potential of sensing technology. However, in the analysed works, there was a lack of effective integration with the human factors and of preserving human life, preventing accidents and occupational diseases. The mining sector needs to take advantage of the tools currently available in order to create more cost-effective productions that are, at the same time, safe for workers and for the environment.

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